

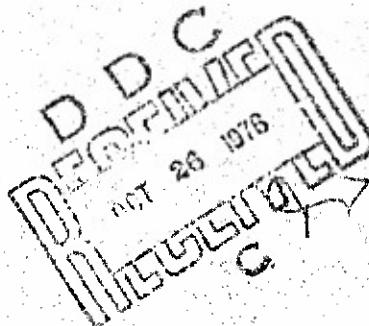
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TECHNICAL REPORT

TR 76-7 AMEL

CAMOUFLAGE STUDY OF GENERAL PURPOSE SMALL  
AND GENERAL PURPOSE MEDIUM TENTS



DEC 1974

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UNITED STATES ARMY  
RESEARCH AND DEVELOPMENT COMMAND  
WATERTOWN MASSACHUSETTS 01760



Aero Mechanical Engineering Laboratory

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19. ABSTRACT (Continue on reverse side if necessary and identify by block number) <i>(20) This study has developed one camouflage pattern for the General Purpose medium and General Purpose small tent which was submitted for field evaluation by MASSTEC. Two additional patterns were developed which are worthy of further evaluation. An overcoloring formulation was developed which is compatible with the FWWMR finish on the cotton fabric used for military tents. Field application techniques were developed for applying the patterns and the overcoloring compounds to the tents. Although the overcolorants developed are worthy of field evaluation they should not be considered a final product for mass production. Further</i>			

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20. Abstract (cont'd)

studies are needed to reformulate the compound to minimize gloss, reduce cost, and improve its covering power and IR reflectance.

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## SUMMARY

The Franklin Institute Research Laboratories (FIRL) conducted a camouflage study of General Purpose (GP) small and General Purpose (GP) medium tents for the U.S. Army Natick Research and Development Command under contract No. DAAK03-74-C-0074.

The objectives of the project were:

To develop camouflage patterns to be applied to the tents which would render them less detectable when located in a temperate zone foliated area and observed from distances of 300 m with the unaided eye, 600 m with 7x50 binoculars, and 8 km at 300 m altitude with aerial photography. Color and color reversible film were also considered as detection methods.

To develop colorants applicable to the tentage material which would be compatible with the surface and which would not compromise the effectiveness of the Fire, Water, Weather and Mildew Resistant (FWWMR) finish. Covering power, blendability and effectiveness when viewed with infrared (IR) film were considered of paramount importance.

To define pattern and overcolorant application techniques which could be employed in a field environment by Army personnel.

To provide guidance for development of patterns for varying backgrounds.

The study did not consider methods of tent redesign, application of camouflage nets, shadow disruption, or any other scheme except application of patterns and overcolorants to the existing tent surface.

In order to avoid duplication of prior efforts, a major camouflage conference was held at The Franklin Institute midway through the project. A complete report on the conference and attendee remarks is presented. Subsequently, The Franklin Institute research team visited Ft. Belvoir for more detailed data. In addition, the Ferro Corporation was employed to aid in overcolorant development based on their prior experience in IR pigments.

The outputs of this study include:

One pattern referred to as the "Nature Pattern" submitted for field evaluation by MASSTER.

Two other patterns worthy of further development.

An overcolorant formulation compatible with tent fabric and the Fire, Water, Weather and Mildew Resistant finish (FWWMR).

Field application techniques for the patterns as well as the overcolorants.

Although the overcolorants developed are worthy of field evaluation and possible use, they should not be considered a final product for mass production. Further studies are suggested to find a suitable replacement of the polyvinyl chloride binder material, which may be withdrawn from the market. (One large chemical firm has already stopped production of this chemical. It remains to be seen whether other major producers of polyvinyl chloride will also discontinue production.) In addition, a further information refinement is needed to minimize gloss and optimize pigment load for covering power and infrared (IR) reflectance.

## PREFACE

The report was prepared jointly by the Franklin Institute Research Laboratory under U.S. Army Contract No. DAAK03-74-C-0074 and the NARADCOM. The work was carried out under the direction of Dr. Constantin J. Monego and Mr. William B. Bushnell of the U.S. Army Natick Research and Development Command acting as Project Officers. The work was supported by the Lead Camouflage Laboratory (STSFB-M) at Fort Belvoir, VA under procurement work directives dated 4 January 1973 FY73 #AL-3-A3164-01-EF-BG and FY74 #AL-4-A4079-01-EF-EP, CLL-1773, Ref. #1613574.

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## CAMOUFLAGE STUDY OF GENERAL PURPOSE SMALL AND GENERAL PURPOSE MEDIUM TENTS

### INTRODUCTION

The Franklin Institute Research Laboratories (FIRL) conducted this study for the U.S. Army Research and Development Command (NARADCOM) and the U.S. Army Mobility Equipment Research and Development Center (MERDC). The Philadelphia College of Textiles and Science, Ferro Color Division and Keystone Aerial Surveys assisted FIRL.

### OBJECTIVE

The objective of Natick Research and Development Command Contract No. DAAK03-74-R-0031 was a study concerned with the camouflage of Army tents designated as General Purpose (GP) small and General Purpose (GP) medium. The primary goals of the effort were to:

- (a) Develop an optimum camouflage pattern design for these tents against Temperate Zone foliated terrains.
- (b) Develop weather resistant colorants for each of the several areas of the proposed pattern for application to and compatible with the surfaces of existing tents made from fabrics finished with Fire, Water, Weather and Mildew Resistant finish (FWWMR) and light dry finish.
- (c) Define the surface preparation and other conditions necessary for the application of the developed colorants to the tents.
- (d) Provide guidance as to further effort that may be appropriate in reference to:
  1. Tent configuration and surface texture.
  2. Patterns for open earth or sandy areas.

Pattern design was de-emphasized in the latter stages of the project, however, early project progress did lead to interesting concepts worthy of further study. These concepts are reported in detail.

### BACKGROUND

Recent camouflage pattern design efforts by the U.S. Army Mobility Research and Development Center at Fort Belvoir, Virginia have led to designs which were judged to

be effective for vehicles in temperata zone foliated areas. Color schemes were devised and specifications generated for paint formulations (anamal base) which contained pigments responsiva to infrared (IR) camouflage detection film.

Application of this technology to fabric material such as tentage and vehicle tarpaulin was not possible because anamal base paints are not compatible with tha flexibility requirement of tentage metariel. In addition, since ell tentage is treated with an FWWMR coating to protect it from fire, water, weather and mildew, it is imperative that all additives be compatible with the FWWMR finish. Additions must not compromise the FWWMR protective capabilities.

There exist many thousands of tents in inventory which should be retrofitted with camouflage. Techniques for application of overcolorants must address this problem as well as the problem of applying overcolorants to new tentage. Existing stock has an olive-drab coloring with low infrared reflectance. Overcolorants must have sufficient opacity to hide this base color.

Infrared photographic techniques such as reverse color film are capable of distinguishing small variations in spectral reflectance. This means that effective camouflage must minimize probability of detection by not only the naked eye, binoculars, black and white film, color film, but also black and white IR reverse and IR color reverse film. Protection must be afforded from ground troops, troops observing from positions higher than the camouflage item (hills, mountains, etc.,) and aerial observation.

Further complications are related to distances. Relatively small patterns are essential to reduce near observation while larger patterns are required for greater distances. Additionally, background content is likely to differ with the angle of observation. For instance, ground level observation is likely to have a tree line background while aerial observation is apt to see "blotches" of grass and earth as a background.

This project addressed itself to minimizing the probability of detection when the item is located in a temperate zone foliated terrain and emplaced against a tree line. The detection techniques considered were the unaided eye, 7 x 50 binoculars, color film and color infrared (IR) film (color reversible film). The distances of observation were 300 m (1000 feet) for the unaided eye, 600 m (2000 feet) for the 7 x 50 binoculars and 8 m (5 miles) for aerial detection at 300 m (1000 feet) altitude.

Constraints were that nothing could be added to the tents other than overcolorants. Nets, outline disruptors, etc., were not to be applied. Glossy appearance and specular reflections were to be minimized. Spectral reflections over the visible and near infrared spectral regions were to be controlled in accordance with the background.

## APPROACH

The general philosophy FIRL applied throughout the study was to avoid duplication of prior effort. Close rapport was established and maintained throughout the project with Natick personnel. Following initial studies and prior to implementation of concepts, FIRL/Natick sponsored a joint camouflage conference at FIRL. Appendix A is the camouflage conference report.

The results of the conference were many useful comments offered by army combat arms officers and a subsequent visit to MERDC, which elicited constructive criticism and acquainted FIRL personnel with existing capabilities at MERDC.

Ferro Corporation was found to possess expertise directly related to the goals of the project. Ferro scientists were extremely cooperative and made significant contributions to the development of effective overcolorants.

## OVERCOLORANT DEVELOPMENT

Overcolorants were developed by reviewing the constituent elements of the existing FWWMR finish, searching the literature for compatible materials, conducting lab tests on pigment loads and formulations, making sample patterns, field testing candidate results, and reiterating the entire procedure to optimize performance.

## SPECTRAL RESPONSE OF PIGMENTS

Spectral reflectance curves were made available by Natick Research and Development Command, on:

1. Standard 4-Color Camouflage Colored Fabrics Dark Green, Ferro Black, Sand and Field Drab (Table 2)
2. Modified 4-Color Camouflage Pattern (Foliated areas)
3. Modified 6-Color Camouflage Pattern (Desert areas)

From Ferro-Color Corporation, Cleveland, Ohio, spectral curves and tabulated spectral data (values every 10 nm) were received on the following pigments:

V-6951 Yellow       $\text{Fe}_2\text{O}_3$  oxide

K-639 Green      Co Ti oxide

V-9112 Yellow      Ti Sb Cr oxide

F-6111 Brown      Fe Cr Zn oxide

V-6782	Black	$Sb_2 S_3$
R-2199	Red	$Fe_2 O_3$
2100	Yellow	$Fe_2 O_3$ oxide
4100	Yellow	$Fe_2 O_3$ oxide
$TiO_2$	White	
V9420		Ni Ti Oxide

Spectral date on green forest and autumn forest background were obtained from the Air Force Cambridge Research Center (AFCRD) Handbook of Geophysics.

Spectral response curves for Kodak Infrared film type 2443 and Color Reversal film type 2448 were obtained by writing to the manufacturer.

A computer program was written in Fortran IV to calculate the spectral response of a pigment illuminated by sunlight to the two types of film plus the CIE Y-response (referred to as eye response). Each of the three film responses (cyan, magenta, and yellow) are maintained separately. The program gives both a list of the reflectance value (response every 10 nm between 350 and 950 nm) and draws seven graphs for each pigment. The seven graphs consist of the single (Y) eye response the three color film responses and the three infrared film responses. The program has been run on the Univac 1108 computer for the six modified pigments for which data was received from Natick.

Literature surveys were conducted to provide technical data for potential candidate pigments and mixtures to support the requirements for spectral response as defined in the analytical tasks of the program.

Computer printouts of the spectral response of pertinent standard color pigments and backgrounds taken from the literature are presented in Appendix A.\* The curves presented refer to the 4-color personnel camouflage pattern currently in use. Similar curves exist for the 6-color pattern also. Note the relative peaks for each curve. The ideal camouflage colors match the spectral response of the color scheme with that of the background.

\*Camouflage Conference Report 73 to 84 (see references)

## **FIELD APPLICATION TECHNIQUES**

This section details health hazards, environmental conditions necessary for application, and application guidelines.

### **List of Materials:**

FWWMR Fabric

Camouflage Overcolorant, Black (B)

Camouflage Overcolorant, Field Drab (FD)

Camouflage Overcolorant, Dark Green (DG)

Camouflage Overcolorant, Sand (S)

Methyl Ethyl Ketone (MEK)

Spray gun complete with air supply, power and oxygen supply mask.

Paint brush (3" - 5" width)

Paint mixing device (power or manual)

6-Foot Rule

Rags

Lifts (e.g., cherry picker, forklift with cage, etc.)

Gloves

### **Health Hazards:**

The camouflage overcolorant compound contains two chemicals which require special consideration for safe handling.

Polyvinyl Chloride (PVC) is a potentially toxic compound which should not be inhaled.\* When a person is exposed to an overcolorant (including mixing, handling and spraying), a protective mask with a separate air supply should be worn at all times, especially indoors. Unmasked personnel should not be within approximately thirty meters of the exposed or sprayed compound (Nota: This distance varies with weather conditions).

Methyl Ethyl Ketone (MEK) is a flammable solvent which is used for cleaning brushes, spray equipment and personnel. (It may be used to dilute the overcolorant for spraying, if necessary).

Prolonged inhaling of MEK should be avoided. MEK may be used in contact with the skin for cleaning, but the skin should be thoroughly washed immediately thereafter. Frequent use should be avoided. Do not allow MEK to come in contact with the eyes or body openings (such as mouth, ears, cuts, etc.). Smoking, lighted material, sparks or excessive heat should not be allowed in the area because MEK is flammable.

#### Preparations:

FWWMR fabric must be clean, dry, and fieldworthy. Overcolorants should be thoroughly mixed. Spray equipment must be clean and free of residuals which may interfere with an even spray.

### PATTERN DESIGN

#### PATTERN SIZE

Approach: Some preliminary estimates of limiting sizes of the pigmented areas for camouflaging the tents were made. First efforts were initiated by scaling up by a factor of five and ten, the patterns used in the current Natick pattern for camouflage clothing.

Pictures taken at the FIRL test site were studied to note the natural phenomena of tree and brush growth. Techniques such as defocusing the pictures highlighted interesting features. For instance, trees tend to grow in "patches" but as they mature, their branches fill in voids between patches which means that dark clumps of trunks have lighter spaces between them but as one looks higher, the branches intermingle into a fairly constant color somewhere between the dark trunks and lighter spaces.

A rear projection system was set up to facilitate study of designs and evaluation techniques. Sketches were made of a number of scenes and characteristic parameters were superimposed on backgrounds of tree lines.

\*William-Steiger Occupation Safety and Health Act of 1970.

Study of the available data on seeing processes and the natural camouflaging properties in the animal kingdom discloses a variety of means and principles that are applicable to tent camouflage. Without trying to prepare a comprehensive listing, the dominant facts can be enumerated in three categories: Human seeing characteristics, spectral data with regard to background, and camouflaging principles applicable to making a tent with foliage background less recognizable to the human observer.

#### HUMAN SEEING CHARACTERISTICS

1. The eye tends to adapt to the average value of two stimuli, e.g., tent fabric, ground, rocks and leaves. The average value of tent color, shade, texture, etc., should be made to resemble the average background.
2. The fidelity with which colors are perceived is approximately the same, e.g., saturation of color in the tent should match that of the background.
3. A high contrast object appears sharper than a low contrast one.
4. A less sharp border area is perceived as having less color saturation.
5. Juxtaposition of two differently colored objects enhances differences in saturation.

#### Background Spectral Characteristics:

1. The color saturation of natural backgrounds (foliage, rocks, earth, etc.) on the average is a maximum of 40%.
2. Dominant wavelengths of grass and foliage are between 560 and 580 nanometers; of earth are between 575 and 585 nanometers.
3. Saturation is quickly lost with distance, and the dominant wavelength shifts toward 475-480 nanometers for long atmospheric paths.
4. Foliage on the average is a minimum of 40% reflective in the infrared (700-1000 nanometers).

#### Camouflage Principles:

1. Color differences are obliterated by color resemblances.
  - a. Individual tent colors are to resemble individual leaf and tree trunk colors.

- b. When distance precludes resolution of patterns and leaves, the blended result is that the tent and background blend in color.
- 2. Light and shade are neutralized by countershading.
  - a. The tent tops and edges are to be toned darker than the sides.
  - b. The end panels of the tent are to be a lighter tone than the long sides.
- 3. Disruptive patterns disguise outline and surface continuity.
  - e. Fine vertical pattern visible through the top edges.
  - b. Tree trunk pattern visible near side edges.
  - c. Severe pattern, which is not predominantly vertical.
- 4. Surface discontinuity masked by coincident pattern.
  - a. Top-to-side pattern continuous — especially as viewed from the air.
  - b. Sides to have bushy/foliage profile.
- 5. Shadow concealed by structural devices.
  - a. Locate tent inside tree line.
  - b. Appendages to tent (out of scope).

#### Tent Characteristics:

Tent characteristics are arranged into the following five categories:

- 1. Outlines
  - Straightness-rectangular outline.
  - Horizontal and sloping lines.
- 2. Size
  - Much larger lateral extent than individual background objects.

3. Surface

Flat, extended surfaces.

Sag between poles caused in part by ropes.

4. Color

Hue visually compatible with background, but sheen and texture incompatible.

5. Shadow

Large, homogeneous.

Sag shadows.

## CAMOUFLAGE GOALS

Camouflage goals can be listed in order of the principles as suggested in the following:

1. Color Difference Obliterated by Color Resemblance.

- a. Individual colors of tent pattern to match individual colors of background leaves, tree trunks, etc.
- b. Blended colors of tent to match blended colors of background. When distance precludes resolution of patterns and leaves, the blended result should be that the tent blends with background.

2. Light and Shade Neutralized by Countershading.

- a. Tent top and tent edges to be toned darker than sides.
- b. Front panels of tent to be a lighter tone than the long sides.

3. Disruptive Patterns to Disguise Outline and Surface Continuity.

- a. Fine vertical pattern visible through top edges.
- b. Tree-trunk pattern visible near side edges.
- c. Possible severing pattern, which is not predominantly vertical.

4. Surface Discontinuity Masked by Coincident Pattern.
  - a. Top-to-side pattern coincident — especially as viewed from the air.
  - b. Sides to have bushy profile.
5. Shadow Concealment by Structural Devices.

Only possibility is placement of tent inside tree line.

#### PATTERN SELECTION AND APPLICATION

Camouflage patterns are designed to:

- disrupt the outline of the item
- cause the body of the item to blend in with its background
- make the item appear to be discontinuous
- provide protection from detection from 500 meters by virtue of its individual sections
- provide protection from detection for distances greater than 500 meters by causing a blending of section of the camouflage pattern
- provide protection from aerial reconnaissance or detection

Camouflage overcolorants are designed to:

- enhance the ability of the pattern to accomplish its goals
- provide protection from detection by color IR and black and white IR photography

Pattern lines are guides to the painter. Slight overlapping of colors is acceptable. Overcolorants should be applied in thin layers. Avoid "running" of colors or excessive buildup which will result in gloss. Coverage should be sufficient to hide the base color of the fabric.

Apply colors in the following order:

Black

Dark Green

Field Drab

Sand

Keep in mind that camouflage is designed to afford protection from distances of hundreds of meters. Slight imperfections or incomplete covering of pattern outlines are of no concern. These conditions are not detectable beyond 20 or 30 meters.

Tent guy lines should be thoroughly covered with a random pattern. At least two overcolorants (and no more than three) should be used on each guy line. The minimum length of a pattern on a line is 30 cm (one foot).

Flaps and tiedowns must be painted on undersurfaces as well as top surfaces.

Patterns selected for field testing were:

MERDC pattern

Scaled up version of 4-color personnel camouflage pattern

Artist's concept of background ("Nature" Pattern)

Zebra pattern

As agreed with MERDC personnel, the MERDC pattern was applied to one GP small and GP medium tent, to be sent to MERDC for their evaluation and possible field tests. The scaled-up version of the personnel pattern was not applied to tentage to be submitted for further testing. The artist's concept of the background was applied to one GP small and one GP medium tent under separate contract, and sent to MASSTER for field test. This pattern is referred to as the "Nature" pattern.

## LABORATORY AND FIELD TESTS

### LABORATORY TESTS

Laboratory tests consisted of mixing and milling of small sample formulations which were used to study the physical characteristics of the overcolorants. Relative pigment

loads were adjusted for color matching and covering power. This proved to be a difficult task because variations in duration of milling and type of mill used was very important in determining the final colorations. Dispersion of pigments (especially the yellow pigment) was critical. Ferro Corporation, NARADCOMM and MERDC conducted spectrophotometric analyses of candidate formulations. The U.S. Testing Company conducted fire and water repellency tests. FIRL checked the covering power and the IR response of each color by placing chips of each color among freshly cut foliage and taking photographs with color and IR reversible film. FIRL used FWWMR-treated duck to make the color chips.

Table 1 is the U.S. Testing Company report. It concludes that MOD 4 formulas did not compromise the FWWMR finish. MOD 5 merely adjusted the relative pigment loads of MOD 4 and replaced talc with diatomaceous earth (Celite). Therefore, it was not necessary to repeat the U.S. Testing study for MOD 5.

#### FIELD TESTS

FIRL maintains a field testing facility at Elverson, PA, which was an ideal site for this study. Pictures were taken of the three line backgrounds before and after foliage grew in the spring. Appropriate tent emplacement sites were chosen on the basis of good field tactics. Observation sites were chosen to give the evaluation team realistic data.

Figures 1 through 4 are an artist's sketches patterns of tree lines studied. Figure 1 and Figure 2 show shaded sketches of tree trunks and branches. Note the clusters of trunks and the "cross wind blown" effects of the branches. In reality the branches are reaching for the sunlight between trunks. A general flow is indicated that would not be apparent during the foliated seasons. Figure 3 is a sketch of the same scene under close-up conditions. Figure 4 is artist's generalized impressionistic concept.

Figure 5 shows the FIRL test range at Elverson and the approximate location of the tents. The darkened rectangular areas represent the GP medium tents and the darkened circles represent the GP small tents. North is toward the left of the diagram with East to the right.

Figure 6 is a topographic map of the test site and vicinity. The numbers in the upper central position of the map refer to the following pertinent locations:

- #1: GP Medium Tent #1 (tree line)
- #2: GP Small Tent #1 (tree line)
- #3: GP Small Tent #2 (tree line)
- #4: GP Medium Tent #2 (open grassy area)

TABLE 1  
U.S. Testing Company Report

Test conducted	Ferro Black	Field Drab	Test results				Carbon Black	Specification Requirement
			1 coat	2 coats	1 coat	2 coats		
Leakage after 10 min. (c.c.)	1 39	53	31	3.5	9.0	**	0	6.5
	2 41	77	10	0	2.0	**	0	7.0
Flammability Char Length (in.)	1 2.6	2.4	1.7	2.8	3.4	2.4	2.7	2.5
	2 3.4	*	2.4	1.9	3.4	*	2.3	2.7
Flaming (sec.)	0	*	0	0	*	*	0	0

Comment: During the water penetration test the fabric did not appear to wet out. Leakage was due to "pinholes" in the fabric.

Test performed as outlined in MIL-C-43627; however, due to limitations in the sample size, only two samples of the warp were available for flammability testing and two samples for water resistance, as discussed with Client.

\*Only 1 sample available due to insufficient sample size.

\*\* No tests data available due to insufficient sample size.

\*\*\*MIL-C-43627A Cloth, Duck, Cotton, Plied Yarns, Fire, Water, Weather and Mildew Resistant Treated, Light Dry Finish. (FWWMR)



Figure 1. View of General Tree Line

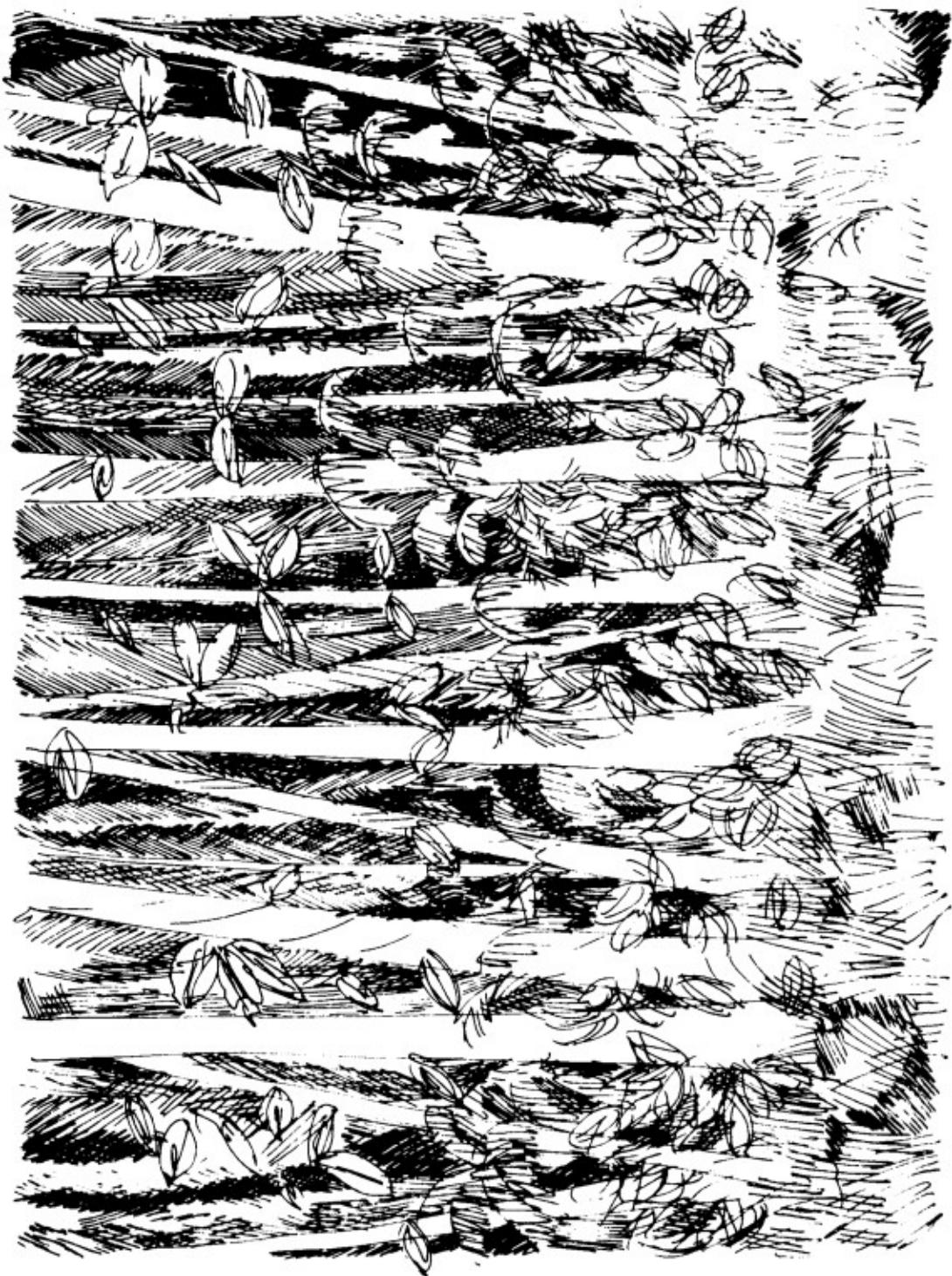


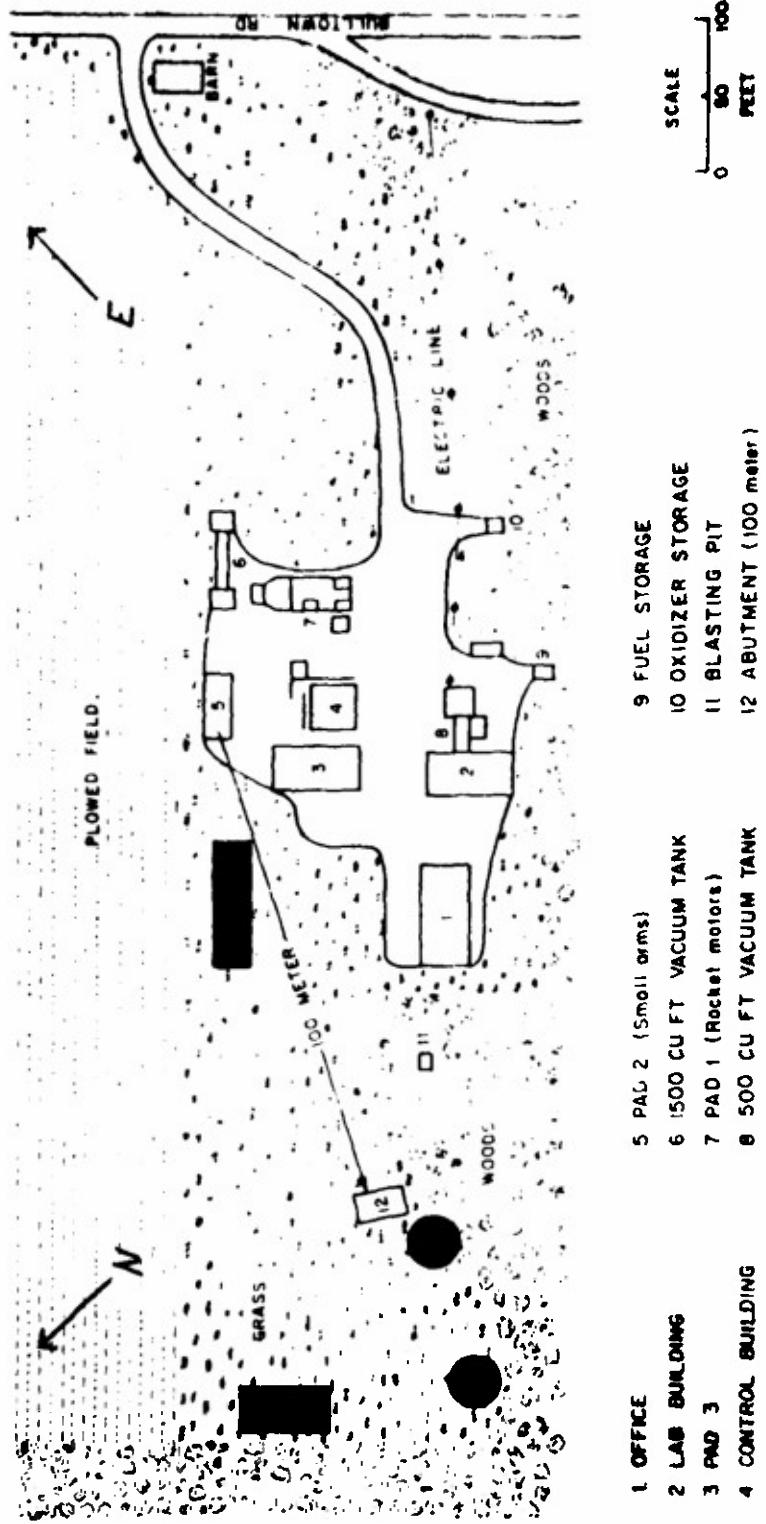
Figure 2. View of Tree Line as It Meets Ground



Figure . . Close-Up of Tree Line



Figure 1. Artist's Concept of Tree Line Camouflage



**Figure 5.** FIRL Test Range, Elverson, PA

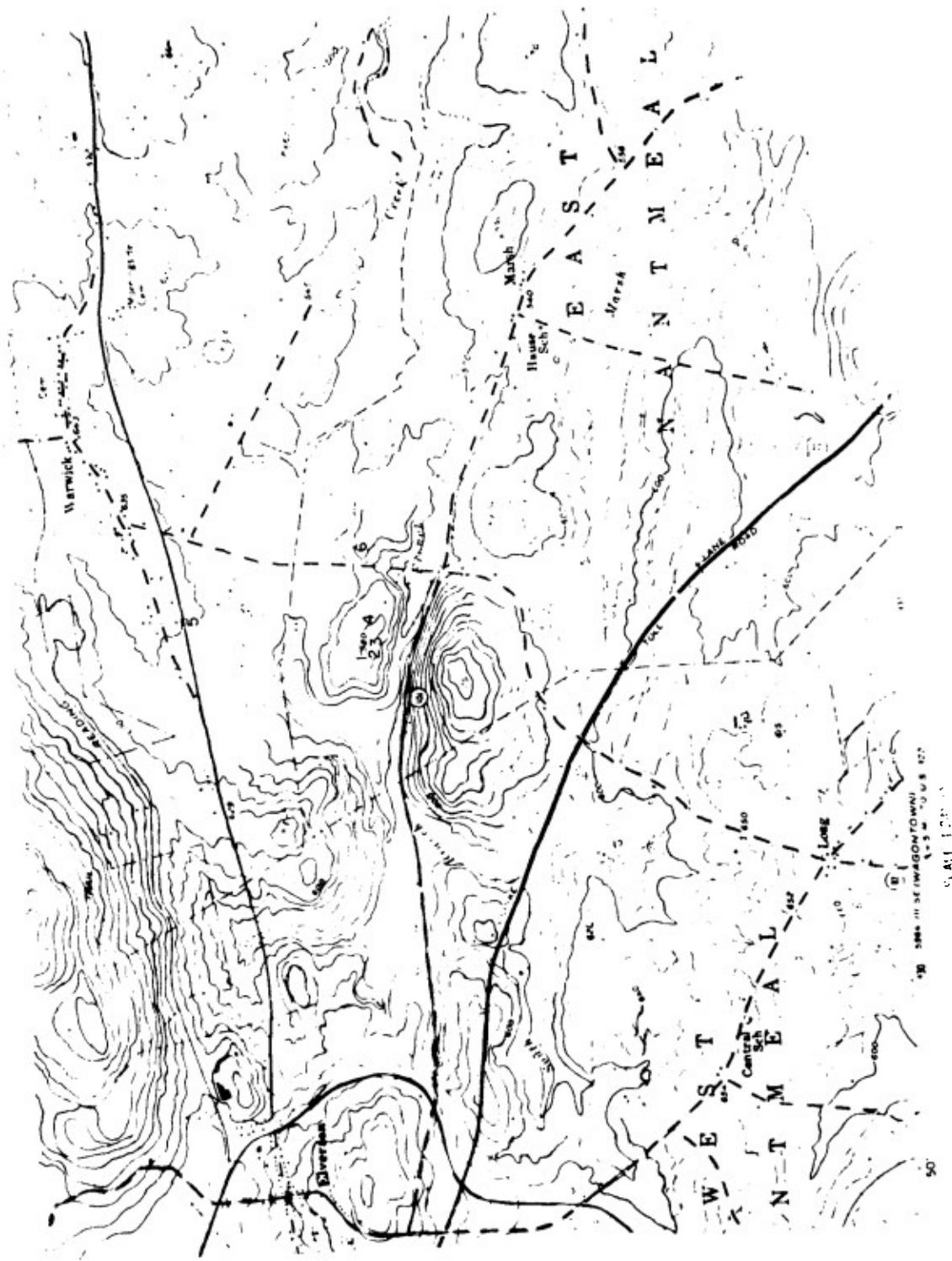


Figure 6. Elverson Topography

#5: Observation Point 1070 m (3500 ft) NNE

#6: Observation Point 550 m (1800 ft) E

Note particularly the relative elevations which dictated the limits on observation sites.

A study of the effect of sun angles was conducted by taking color and color IR photo's at half-hour intervals from sun-up to sundown. This procedure highlighted the camouflage problems as they change during the day in response to sun angle. Early morning and late afternoon presents problems with glossy surfaces on the sides of the tent. Mid-day highlights roof reflectance. Of course, angle of observation plays an important role.

Aerial overflights were conducted during mid-day conditions. Shadows proved to be the most formidable problem in aerial observation. The aerial photographs were the most disappointing part of this program since they were not accompanied by imagery interpretation analysis, such as would be furnished to combat arms officers from a regular surveillance flight made by Army aircraft. It is recommended that in future studies which include aerial observations, that standard Army surveillance aircraft be used and an imagery interpretation report be furnished NARADCOM for study.

## RESULTS

### PATTERNS

Three patterns were selected for further study. In addition, by agreement with MERDC, the MERDC pattern would be applied to a GP Small and a GP Medium tent. The two tents in the MERDC pattern would be sent to Fort Belvoir for their information and future action. Of the three patterns selected in this study, an artist's concept of the natural background, termed "Nature", was selected on the basis of its expected ability to simulate an actual background and its characteristic of smaller sections (effective at 500 meters) blending into larger sections (effective at 2000-4000 meters). A striped pattern, termed Zebra, was selected due to its imitation of some types of natural animal kingdom camouflage. Finally, the pattern used for army personnel camouflage was selected on the basis of use for one-man-sized objects in foliated areas. Its design is expanded tenfold for application to tentage. Only the "Nature" pattern was submitted for MASSTER testing at this time.

Appendix B shows sketches of all patterns and details field application techniques for drawing the pattern on the tentage.

## OVERCOLORANTS

There was a total of five formula modifications. The latest formula is designated "MOD 5". The "MOD 5" is an effective and usable overcolorant formulation which approaches the goals of the study. However, it does have its shortcomings and should not be considered a final product ready for mass production. Table 2 is the list of ingredients, processing techniques, physical properties, spectral properties and accompanying notes. Table 3 shows the quantity of camouflage overcoloring compound used for camouflaging one GP Small and one GP Medium tent (Nature Pattern, two coats). Table 4 shows the cost per liter of the four different overcoloring camouflage colors.

Geon 222, polyvinyl chloride, is possibly a toxic material which Dow Chemical has advised may not be available after January 1, 1975. The concentration of diatomaceous earth (Celite) is apparently not optimal because a degree of gloss still remains. Covering power of the Dark Green, in particular, is insufficient. Further studies to optimize the formulations are indicated.

Gloss measurements by an independent testing company are given in Appendix C. The data in Appendix C indicates that the colors have a reasonably low gloss but can be improved in the reformulation of the overcoloring compound.

## APPLICATION TECHNIQUES

Application of the overcolorants has been accomplished by spray equipment common in the military. The compounds are compatible with canvas and tentage material and they do not compromise the effectiveness of the FWWMR coating.

Surface preparation and other conditions necessary for application are discussed in detail on page 22. The techniques are relatively straightforward and compatible with field conditions. Applications of the pattern to the tentage is discussed in Appendix B, attached.

## CAMOUFLAGED GP MEDIUM TENTS

Figure 7 and 8 illustrate the appearance of a camouflaged GP Medium tent.

Figure 7 was taken using infrared film at FIRL's Elverson Field Test site in Pennsylvania. Note that with the infrared film the green trees turn red in color. Note also the weak red spots appearing on the GP Medium tent. The red spots on the tent are due to the Ferro Black pigments, the weak color is due to insufficient black pigmentation in the four-color MOD 4 overcolorant formulation. The Dark Green

**TABLE 2**  
**"MOD 5"**  
**Overcolorant Formulation and Properties**

Batch Compositions (Parts by Weight)		Percent
1. Polyvinyl Chloride (Geon 222)	100	19.10
2. Cyclohexanone	300	57.20
3. FMC-Tricresyl Phosphate	15	2.26
4. Synpron 966 Barium/Cadmium/Zinc Liquid PVC Heat Stabilizer	10	1.90
5. Chlorinated Paraffin (Chlorowax 70)	25	4.77
6. Inorganic TiO <sub>2</sub> (Oncor 75 RA)	5	0.95
7. Diatomaceous Earth (Celite)	30	5.70
B. Pigment	40	7.62
Total	525	100.00

(Parts by Weight)	Pigments (Parts by Weight)			
	Dark Green	Black	Sand	Field Drab
Ferro Green K639	40	—	4.0	10.1
Ferro Black V67B2	—	40	2.3	3.4
Ferro Yellow V6951	—	—	6.2	10.7
Ferro Brown V6111	—	—	0.5	11.8
White TiO <sub>2</sub>	—	—	27.0	4.0

#### Processing

Dissolve item 1 into item 2 by stirring at room temperature. Stir in the other ingredients. Transfer the mix into a porcelain ball mill, using ceramic balls, and ball mill for one hour.

Table 2 (cont'd)

**Physical Properties**

	Dark Green IE 388-1	Black IE 388-2	Sand IE 388-2	Field Drab IE 388-4
1. Batch Number Kg 11	1.08	1.08	1.15	1.15
2. Hiding Power* (m 2/1)	5.1	17.0	10.9	10.9
3. Contrast Ratio**	0.955	0.875	0.974	0.945
4. Gloss at 60	9	3	16	7.5
5. Hegman Grind	8	0	4	4

\*Pfund Cryptometer

\*\*Black (Y) over white (Y) with 7.5  $\mu\text{m}$  (3-mil) film in the visible spectrum

**Colorimetric Properties**

	Dark Green (IE 388-1)			Black (IE 388-2)		
	Over White	Over Black	Steel STD	Over White	Over Black	Steel STD
Y	0.1064	0.1017	0.067	0.0569	0.0498	0.0400
x	0.323	0.322	0.333	0.304	0.304	0.317
y	0.379	0.377	0.384	0.310	0.309	0.322
I.R.	64.3	36.0	49.6	61.5	51.2	4.5
Red	8.8	8.4	7.45	5.7	4.9	4.2
	Sand (IE 388-3)			Field Drab (IE 388-4)		
	Over White	Over Black	Steel STD	Over White	Over Black	Steel STD
Y	0.3238	0.3154	0.2928	0.1300	0.1228	0.1265
x	0.365	0.365	0.363	0.383	0.388	0.384
y	0.379	0.380	0.373	0.374	0.378	0.381
I.R.	70.3	56.2	61.8	37.3	31.9	28.6
Red	34.9	33.7	34.6	16.9	16.1	16.8

Note: All spectrophotometric data were obtained from dry film applied over a white and black portion of the Morest Card at a 7.5  $\mu\text{m}$  (3-mil) dry film thickness.

TABLE 3

**Quantity of Camouflage Overcoloring Compound Used for Camouflaging One  
GP Small and One GP Medium Tent (Nature Pattern 2 Coats)**

Color	Percent Color in Pattern	Quantity of Camouflage Overcoloring Compound Used for Each Tent	
		GP Small	GP Medium
		liters	gallons
Black	22.5	2.7	0.7
Dark Green	38.3	4.2	1.1
Field Drab	22.5	2.7	0.7
Sand	16.7	1.9	0.5
Total	100.0	11.5	3.0
Area Tent Wall	45.2m <sup>2</sup>	502 ft <sup>2</sup>	87.3m <sup>2</sup>
Covering Power	3.8m <sup>2</sup> /l	167 ft <sup>2</sup> /gal	3.8m <sup>2</sup> /l
			970 ft <sup>2</sup>
			162 ft <sup>2</sup> /gal

The zebra pattern was applied to one GP medium tent. Appendix B, attached, shows detailed pattern schemes and discusses field pattern application techniques.

**Table 4**  
**Cost of Camouflage Overcoloring Compound (MOD 5)**

Color	Cost/liter	Cost/gallon*
Black	\$6.20	\$23.84
Dark Green	5.69	21.85
Field Drab	5.61	21.63
Sand	5.50	21.15

\*Source: Ferro Corporation, Cleveland, Ohio, for 57 liters (15 gal) each of four colors, cost of ingredients, processing distribution for this small quantity.



Fig. 7 General Purpose Medium Tent, MERDC Pattern, MOD 4 Overcolorant  
Formulation, Infrared Film, Elverson Test Site, Elverson,  
PA (FIRL)

Fig. 8 General Purpose Medium Tent, Nature Pattern, MOD 5 Overcolorant  
Formulation Color Film USNDC, Natick, MA (NDC)



formulation did not turn red for the same reason (insufficient pigment in the overcolorant formulation). Based on visual examination of the color match between colors obtained with the MOD 4 overcolorant formulation with the MERDC camouflage color chips and the response of the colors to infrared film, it was decided to enter into the "MOD 5" overcolorant formulation. Figure 8 is a Kodachrome daylight color photograph of a GP Medium tent, camouflaged in the Nature Pattern, using the four-color MOD 5 overcolorant formulation. The photograph was taken at NARADCOM, Natick, Massachusetts.

## CONCLUSIONS AND RECOMMENDATIONS

### PATTERNS

The "Typical" terrain considered by this project consists of a foliated tree line lateral view with a patchy grass and dirt background for higher altitude and aerial views.

The "Nature" pattern considers the positive principles of the MERDC vehicle pattern and blends them with the contours of a "typical" tree line, the concentric section concept, and the considerations dictated by sun angles and vantage point angles (as they affect the observer). The "Nature" pattern will be subjected to an unbiased field evaluation by MASSTER in phase II camouflage test in the summer of 1975. A large number of observers who reflect varied combat arms should be used in this evaluation. For completeness, this field evaluation should be extended to include numerous backgrounds. These should include backgrounds which do not render the target difficult to detect because some degree of protection (at least to the casual observer) is desirable even in exposed areas.

The striped zebra pattern and expanded personnel pattern show some interesting features. For instance, the striped pattern appears to be very effective in breaking the distinguishing features of the tent outline. The expanded personnel pattern proved to be very effective along the ridge beam of the GP medium tent when oriented horizontally. Therefore, these two patterns should be subjected to further field tests to determine if they can be modified to compete with the "Nature" pattern for overall effectiveness.

Open earth or sandy area backgrounds present the same problems and principles as the tree line background. The variations are mainly concerned with color and lack of foliage, and effects of sun angle and shadows. An in-depth study of the effects of sun angles vs background is in order. Repainting of the tents might suffice to accommodate the color and contrast problems. It is agreed that camouflage in open areas, such as sand and open earth, is an order of magnitude more difficult than camouflage against a background such as soliated trees. Nonetheless, the application of these principles will render the targets less detectable. The degree of detectability can only be determined by further field evaluation.

A compendium of typical scenes using time-lapse photography from around the world in which tents might be expected to be placed would be a valuable tool for future pattern designers. This photographic almanac could be computerized. The designer could analyze his pattern superimposed on a background as conditions vary during the day and from day to day. Automation could be added by using a system similar to the method used to convert photographs to paint by number sets. Quantifying the data base, via computer, and yielding an average pattern for varying conditions are within the state-of-the-art.

An example of how these concepts would work is as follows:

Draw the pattern on a TV display with a light pen

Assign colors to the pattern

Call backgrounds of interest from memory

Superimpose pattern on background

Move, enlarge, reduce, reproduce, modify (shape and color) as desired

Modify background, if desired

#### OVERCOLORANTS

The overcolorant formulations are refined to a degree conducive to comparative field evaluations of the patterns. However, MOD 5 compounds should not be considered a fully developed end item.

A serious problem is the dependence upon Geon 222 (a polyvinyl chloride) as the binding agent. Polyvinyl chloride (Geon 222) has been determined by the industrial safety and health act to be a hazardous material, and, due to the cost penalties related to its safe manufacture, it may or may not be available after January 1, 1975. However, other large chemical firms are continuing to make polyvinyl chloride which may serve as a substitute for Geon 222. It is imperative that a study be undertaken to find a more suitable less toxic replacement for this ingredient.

Diatomaceous Earth (Celite) has been used as a delustrant. Earlier formulations used talc. Celite has significantly reduced the glossiness of the end product; however, the gloss is still considered not acceptable. Further formulation development is needed.

The data in Table 2 show that the hiding power of MOD 5 is still not sufficient to cover the substrate at a 3-mil thick application.

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## **APPENDIX A**

### **Camouflage Conference Report**

**Edited by the  
Conference Project Manager  
John A. De Benedictis**

**The Franklin Institute  
Research Laboratory  
Philadelphia, PA 1974**

**July 24, 1974**

## **Appendix A**

### **Camouflage Conference Report Issued to Attendees**

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## 1. INTRODUCTION

The Mobility Equipment Research and Development Center (MERDC) at Fort Belvoir, Virginia is engaged in camouflage assessment activities for the U.S. Army. One of their current requirements is to camouflage GP small and GP medium tents. The U.S. Army Natick Research and Development Command, has as one of its primary responsibilities, the protection of tentage material as it relates to fire, water, weather and mildew resistance (FWWMR). Due to its knowledge of textiles, colorants and related expertise, Natick assumed responsibility for the camouflage of tentage. Subsequently, the Franklin Institute Research Laboratories, due to its prior experience in camouflage, in-house capabilities in optics, materials, chemistry and field studies and access to reliable subcontractors in the textile and aerial photographic fields, was awarded a contract on open procurement. The objectives of this contract are:

- (a) Develop an optimum camouflage pattern design for GP small and GP medium tents against temperature zone foliated terrains.
- (b) Develop weather resistant colorants for each of the several areas of the proposed pattern for application to and compatible with the surfaces of existing tents made from fabrics finished with FWWMR and light dry finish.
- (c) Define the surface preparation and other conditions necessary for the application of the development colorants to the tents.
- (d) Provide guidance as to further effort that may be appropriate in reference to:
  1. Tent configuration and surface texture.
  2. Patterns for open earth or sandy areas.

The project has progressed to the point where FIRL has three patterns and a number of candidate overcolorants for consideration. The patterns are:

A vehicle pattern designed and tested by MERDC. (An application concept for tentage was also published but never tested).

An enlarged version of the Army personnel camouflage pattern.

A creative "artist's concept" approach to quantizing backgrounds.

This conference was convened in order to gain the special insights available from field officers responsible for camouflage in various army commands and research centers.

Their comments, suggestions, recommendations and their descriptions of real-life field problems and philosophies were particularly helpful at this pivotal decision making juncture.

The list of attendees is presented in Table A-1.

**Table A-1. List of Attendees**

Name	Organization
Dr. Constantin Monego	U.S. Army Natick Research and Development Command
William Bushnell	U.S. Army Natick Research and Development Command
Basil Natsios	U.S. Army Natick Research and Development Command
Dr. James McLeskey	Ft. Belvoir (MERDC) Va.
Capt. Gary Sevinge	B2nd Airborne, Ft. Bragg, No. Carolina
Lt. Michael J. Moore	1Bth Airborne, Ft. Bragg, No. Carolina
Capt. David E. Cowley	4th Infantry Div., Ft. Carson, Colorado
Lt. Col. Ronald Metzger	MASSTER, Ft. Hood, Texas
Maj. Richard B. McDermott	MASSTER, Ft. Hood, Texas
Capt. Robert E. Travis	1st Cavalry Div., Ft. Hood, Texas
Col. Howard V. Keighler	2nd Armored Div., Ft. Hood, Texas
Capt. Richard J. Dunn	101st Airborne Div., Ft. Campbell, KY
Lt. James J. Knowles	101st Airborne Div., Ft. Campbell, KY
Could not attend	
Col. Davis	G2 Ft. Lewis, Washington, DC
Col. Born	1st Infantry
<b>FIRL PERSDNNEL:</b>	
John A. DeBenedictis	Administration
John Woestman	Optics
Robert Florentine	Chemistry
Edmond Dougherty	Field Studies
<b>TEXTILE PERSONNEL:</b>	
Fred Fortress	Textile Compatibility
Betsy Damos	Application Techniques

## 2. ORIENTATION

On Monday, July 22, 1974 at 2030 hours an orientation meeting was held at FIRL.

Dr. C. Monego, Project Officer representing the U.S. Army Natick Research and Development Command gave a brief introduction explaining Natick's history and current responsibilities as they apply to the current project. In essence, Natick must ascertain that any additions to the tentage does not compromise the effectiveness of the FWWMR properties. They are also interested in application techniques as they apply to retrofitting of the in-stock tentage as well as field application and application techniques as they apply to new fabrications of tentage. A further concern is minimizing the weight added by camouflage over colorants. Natick has conducted studies in regards to color and color IR properties of Ferro Corporation pigments.

John A. DeBenedictis, Project Leader at FIRL, discussed the FIRL organization as it relates to the current project, past experiences in the camouflage area, current objectives, individual members of the camouflage team, project progress to date, future plans and the itinerary for the conference.

The Research Labs (FIRL) was incorporated shortly after WWII and is dedicated to R&D for both government and industry highlighting engineering as well as the soft sciences. The four major departments within FIRL are Life and Physical Sciences, Energy and Environment, Systems Science (SS) and Science Information Services (SIS). This project is primarily associated with Life and Physical Science and, in particular, the disciplines of Optics, Materials and Chemistry within that department. SIS has been useful in conducting pertinent literature searches.

FIRL camouflage experiences have included:

Development of nets for camouflage (1958).

Reduction of glare from helicopter windshields, rotor blades and rotor hub (1970).

Application of reflective material to camouflage.

New concepts.

- "instantaneous" camouflage
- "pop-up" camouflage
- inflatable camouflage
- elimination of shadows
- chameleon color change

Next, Mr. DeBenedictis reviewed the project objectives and defined the scenario for detection as:

300 m (1000 feet) to the unaided eye

600 m (2000 feet) to a 7x50 binocular

300 m (1000 feet) altitude and a 8-kg (five-mile) range to aircraft (eye and binocular)

These vantage points are as defined by the contract. Of further interest is detection by color film and color IR (camouflage) film.

Table 2 discusses the research team assembled for the project.

Dr. C. Monego is the Project Officer from Natick and is responsible for liaison between FIRL, Natick and MERDC as well as other government agencies and overall project direction. William Bushnell is his assistant.

John A. DeBenedictis is the Project Leader at FIRL and is responsible for project implementation, adherence to the objectives, successful completion of all tasks on time and within budget and sponsor liaison.

Table A-2. Research Team

**U.S. ARMY NATICK RESEARCH AND DEVELOPMENT COMMAND**

Monego: Project Officer

Bushnell: Assistant Project Officer

**FIRL**

DeBenedictis: Administrator

Woestman: Optics & Spectral Properties

Florentine: SOA in Colorants and IR detection

Dougherty: Field Studies and new concepts

**PHILADELPHIA COLLEGE OF TEXTILE & SCIENCES**

Fortess: FWWMR Compatibility & Formulations

Damos: Application Techniques

**KEYSTONE AERIAL SURVEYS**

Schmunk: Aerial Photography

John W. Woestmen concerns himself with the geometric optics and spectral properties of the tentage and overcolorants. Dr. Robert Florentine is responsible for application of the state-of-the-art techniques in colorants and IR detection as they relate to the objectives of this report.

Edmond J. Dougherty is responsible for all field studies and development of new concepts in pattern design.

Professor Fred Fortress applies his expertise to developing overcolorant formulations compatible with tentage, non-invasive to the FWWMR finish and effective in camouflage integrity. Professor Betsy Damos concentrates on application techniques as they apply to the field environment as well as factory retrofitting of existing tentage and manufacture of new tentage.

John Schmunk of Keystone Aerial Surveys has the equipment and expertise for high quality aerial photography. He will have the pictures taken and processed as appropriate.

Table A-3 summarizes the project progress to date.

Liaison with most of Natick personnel, some of MERDC personnel and Ferro Corporation has been established. Background scenario has been limited to a dense tree line (Studies include both defoliated and foliated conditions). Defoliated studies indicate that trees grow in clusters and their branches reach for sunlight between the clusters, giving a cross wind blown effect. Spectral response curves have been computer generated based on the literature for four of the standard pigments (black, brown, dark green, light green), Autumn Forest/ripe field and Forest green grass. Measured data from actual pigment formulations will be processed and compared to this data. The three different patterns implemented to date (in the form of 1 m (3 feet) by 6.7 m (20 feet) samples) are the MERDC pattern, a 5 times enlargement of the army personnel pattern and an artist's mural type sketch of the background in question.

**Table A-3. Progress to Date**

Liaison with NATICK/MERDC Personnel

Tree line characteristics

Defoliated (trunk clusters, cross wind blown effects)

Computer Printouts — Spectral Response

Four standard pigments: black, brown, dark green and light green (IR, color, eye)

Backgrounds

Autumn Forest/ripe field — Forest green grass

**PATTERNS:**

Existing:

MERDC (Truck). New Formulas

Personnel (5X)

Artist Mural Type

Concepts

Repeatable Mural

Three-Tone Green

**SUN ANGLE STUDY**

Reduce glare from roofs (sags hurt)

IR-red background

New formulas based on Ferro pigments (designed for camouflage) and FWWMR compatibility have been applied to all the colors in the MERDC pattern (not all colors are good matches, yet) and to all the colors in the expanded personnel pattern except light green. The light green was a poor match and a commercial paint was substituted. Commercial paint was used for all colors of the mural type pattern. New concepts have been generated but not applied. Further pursuit of those ideas will be judged contingent upon the results of this meeting.

Sun angle studies were conducted on non-camouflaged tents by taking color and color IR pictures every half-hour from 0700 to 2100 from various angles and distances. Notable results were glare from the roof of the tents, highlighting of sag points, outstanding guide lines in the IR and the bright red background on IR film.

Future project plans include:

- Spectral response measurements
- Comparison of Spectral response data with the literature
- Optimization of formulations
- New patterns
- Photographic recordings and studies
- Alternate methods

Table A-4 outlines the itinerary for the Conference. (Elverson is the test site located 68 km (44 miles) from Central Philadelphia.)

Table 4. Itinerary for Tuesday

0800	Bus to Elverson (from Penn Center Inn)
0900	Observation at Elverson
1100	Bus to FIRL
1200	Lunch
1245	Conference
DeBenedictis	Introduction
Woestman	Optical Considerations Principles Colors Means to identify methods
Florentine	New Materials IR Studies Efficiency
Dougherty	New concepts in patterns Mother Nature Computer Designs Applications
Fortess	Formulations FWWMR
Damos	Stencils Applications
1400	Coffee Break
1415	Open Discussion
1600	Adjournment

### 3. TEST SITE VISIT

Two GP small and two GP medium tents were erected at the FIRL Elverson test site. The two small tents and one medium were located along the edge of a tree line simulating realistic field emplacements. The tents were not recessed into the tree line as they would normally be because the overbrush would have been too effective in camouflaging the tents without a pattern being applied. The second GP medium tent was located in an open grassy area in order to study the effectiveness of the overcolorants and patterns under extreme conditions.

The conferees were initially transported to the tent site to study the emplacement up close and to observe the patterns. Initially, the three 1 m (3 ft) by 6.7 m (20 ft) rolls of canvas were draped over the GP medium tent against the tree line in a vertical fashion.

Next the observers moved to a vantage point due East of the tents approximately 500 m (1500 feet) away and 6.7 m (20 feet) above the ridge line of the tents. All distant observations were made with the unaided eye and through 7x50 binoculars. The camouflage patterns were reoriented several times and moved from tent to tent as directed by the observers via walkie-talkie. The next vantage point was northeast approximately 934 m (2800 feet) away and 6.7 m 20 feet below the tent site. The final stop was due north 1334 m (4000 feet) away.

The following is a list of pertinent on-scene observations made by the conferees:

(a) From tent site

Tents should be deeper in the tree line

Oblique photos are very important

Conditions are different for roof as opposed to the sides

Probably want vertical patterns at the base and horizontal patterns near the top

Redesign the support poles to give curved effects

Different colored leaves appear to be speckled

The mural type pattern should have a darker green

No vertical or horizontal flow is evident in the mural type pattern

MERDC pattern should have a dark color in place of the sand

Brown in MERDC pattern is too reddish

Expanded personnel pattern has the wrong colors (too much red and too light)

(b) From 500 m (1500 feet)

MERDC pattern looks good on roof

Expanded personnel pattern looks good on sides

Try MERDC pattern with expanded personnel pattern colors

Expanded personnel pattern when re-oriented along upper ridge line looks great except for light green

Try expanding personnel pattern to ten times original

(c) From 934 m (2800 feet)

Colors should be blacker or at least dark green

Pattern should be vertical at bottom and oblique at top

Expect patrols to be observing from distances greater than 300 m (1000 feet)

Change light brown to black

In good weather, the tent sides will be rolled up! Consider effect of mosquito netting. Camouflage netting?

(d) From 1334 m (4000 feet)

Expanded personnel pattern looks good

MERDC pattern would probably look better if it were expanded sideways (cover more of tent)

There are lots of dark spots in background.

Need a pattern within a pattern. That is, from close range, smaller pattern should be effective. From more distant vantage points, small patterns should blend into large patterns.

#### 4. SUMMARY OF FORMAL PRESENTATIONS

Five key members of the camouflage team gave formal discussions concerning their areas of interests. A summary of their discussions follows.

John Woestman — Optics

There are three optical considerations pertinent to the problem at hand. They are:

Human Seeing Characteristics

Spectral Data as Related to Background Spectra

Camouflaging Techniques applicable to tents. Under human seeing characteristics one must consider:

Eye tends to adapt to the average value of two stimuli. Therefore, the tent fabric should resemble the leaves and the general tent colorants should represent an average background.

Colors are perceived with approximately the same fidelity. Saturation characteristics of the tent color must approximate the saturation characteristics of the background.

High contrast objects appear sharper than low contrast objects.

Less sharp border areas are perceived as having less color saturation.

Juxtaposition of two different color objects enhances differences in saturation.

In regards to background spectral characteristics:

Color saturation of natural backgrounds (foliage, rock, earth) are all less than 50%. Most are less than 40%, but foliage is usually greater than 40%.

Dominant wavelengths of grass and foliage are 560-580 nanometers and of earth are 575-585 nanometers.

The effects of distance are that the saturation is quickly lost with distance (function of aerosol content) and the dominant wavelength shifts toward 475-480 nanometers for long paths.

The average infrared reflectance is a minimum of 40% between 700 and 1000 nanometers.

Some interesting tent camouflage principles based on animal and insect camouflage are:

Color differences are obliterated by color resemblances

- Individual tent colors should resemble individual leaf and tree trunk colors.
- When distance precludes resolution of patterns and leaves, the blended result is that tent and background blend in color.

Light and Shade are neutralized by countershading

- Tent top and edges to be toned darker than sides.
- Front panels of tent to be lighter tone than long sides.

Disruptive patterns disguise outline and surface continuity

- Fine vertical pattern through top edges
- Tree trunk pattern near side edges
- Severing pattern, which is not predominantly vertical

Surface Discontinuity Masked by Coincident Pattern

- Top-to-side pattern continuous — especially as viewed from air.
- Sides to have bushy/foilage profile

Shadow concealed by Structural Devices

- Locate tent inside tree line
- Appendages to tent (out of scope)

Fig. A-1 shows the maximum size patterns resolvable as they relate to the unaided eye and the 7x50 binocular aided eye. These facts suggest that individual color patterns should be in the range of 1 to 5 inches. Small groups of individual patterns should dominate the 9 to 40 inch range and large patterns are useful only for long distances.

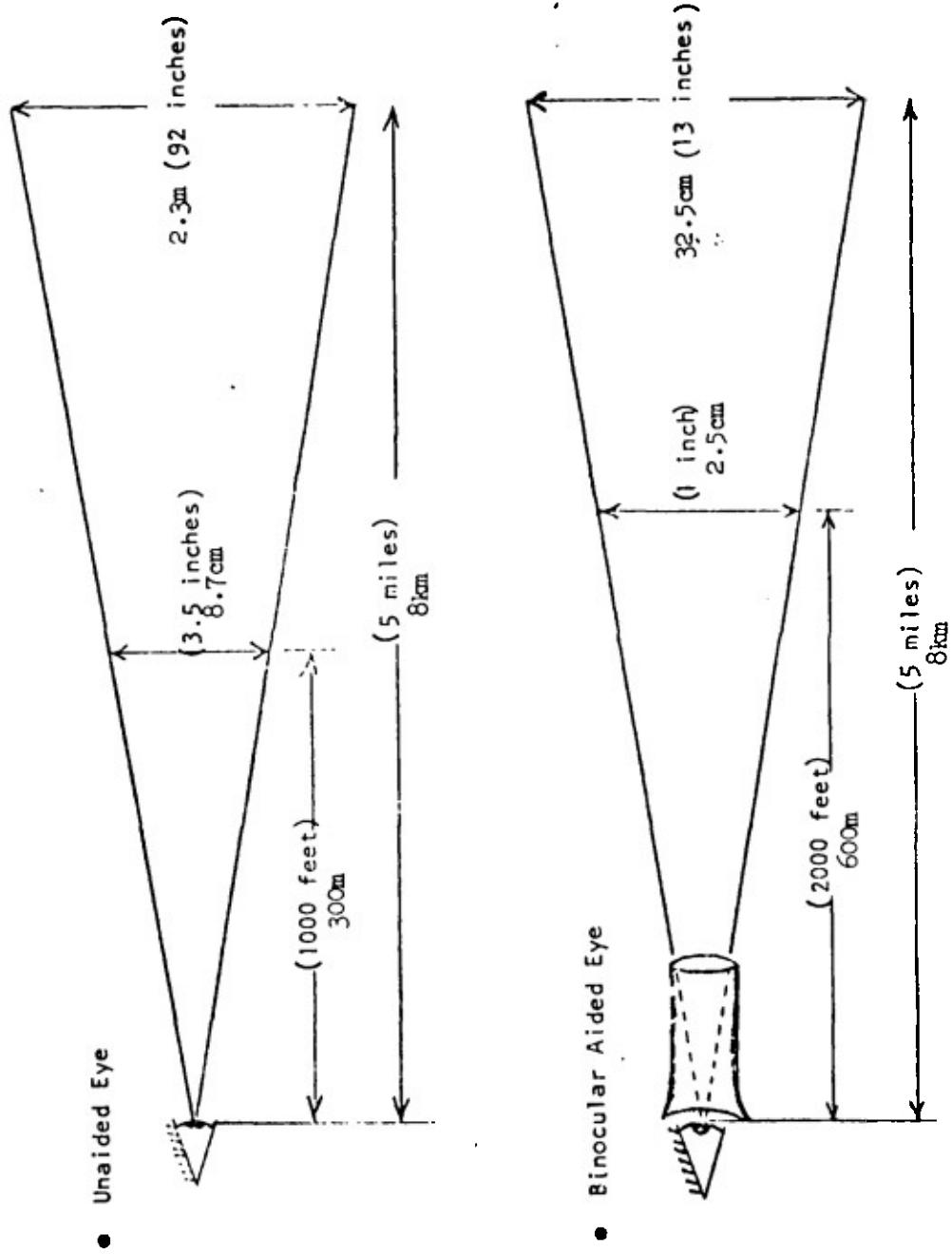


Fig.A-1. Pattern Sizes Resolvable

Some pertinent descriptors for color evaluation to keep in mind for the purposes of this discussion include:

Pure Spectrum

Percent Reflectance versus Wavelength

CIE Tri-stimulus

x, y and Y color coordinates

Color Charts (Pyramid)

Dominant Wavelength and Saturation

Fig. A-2 shows the % reflectance plotted against wavelength of the color tan designated #379.

Fig. A-3 presents Typical Tri-Stimulus curves.

Fig. A-4 shows the color pyramid dominant wavelength and saturation curves.

Factors to consider in the spectral curve composition includes:

Spectral Sources

Noon Sun

Morning/Evening Sun

Overcast Daylight

Camouflage Pigments and Background

Tent Colorants

Grass/Rock Background

Sensors

Eye

Color Film

Cyan - red output

Magenta - green output

Yellow - blue output

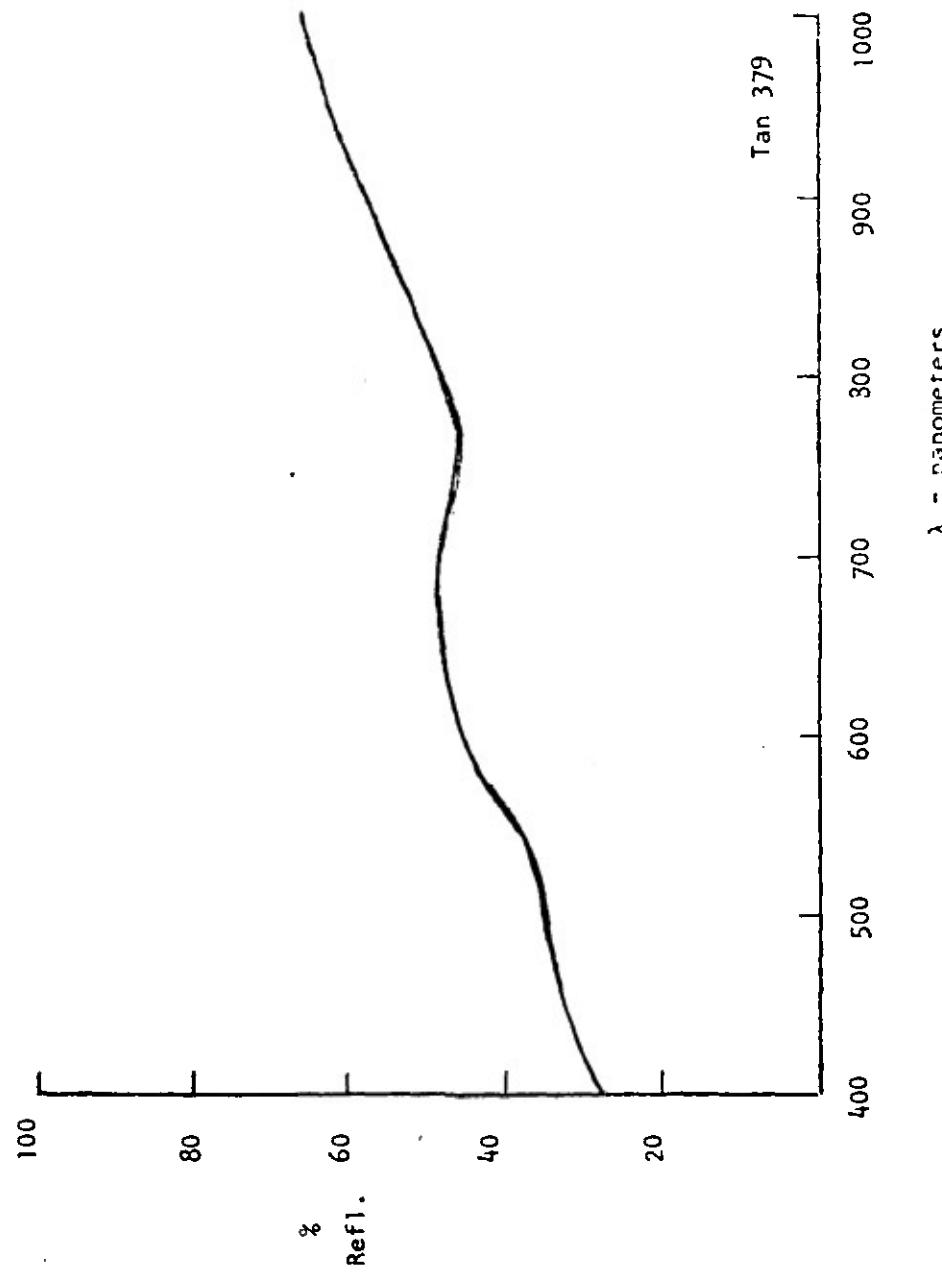


Figure A-2 Measured By Spectroradiometer/Spectrophotometer

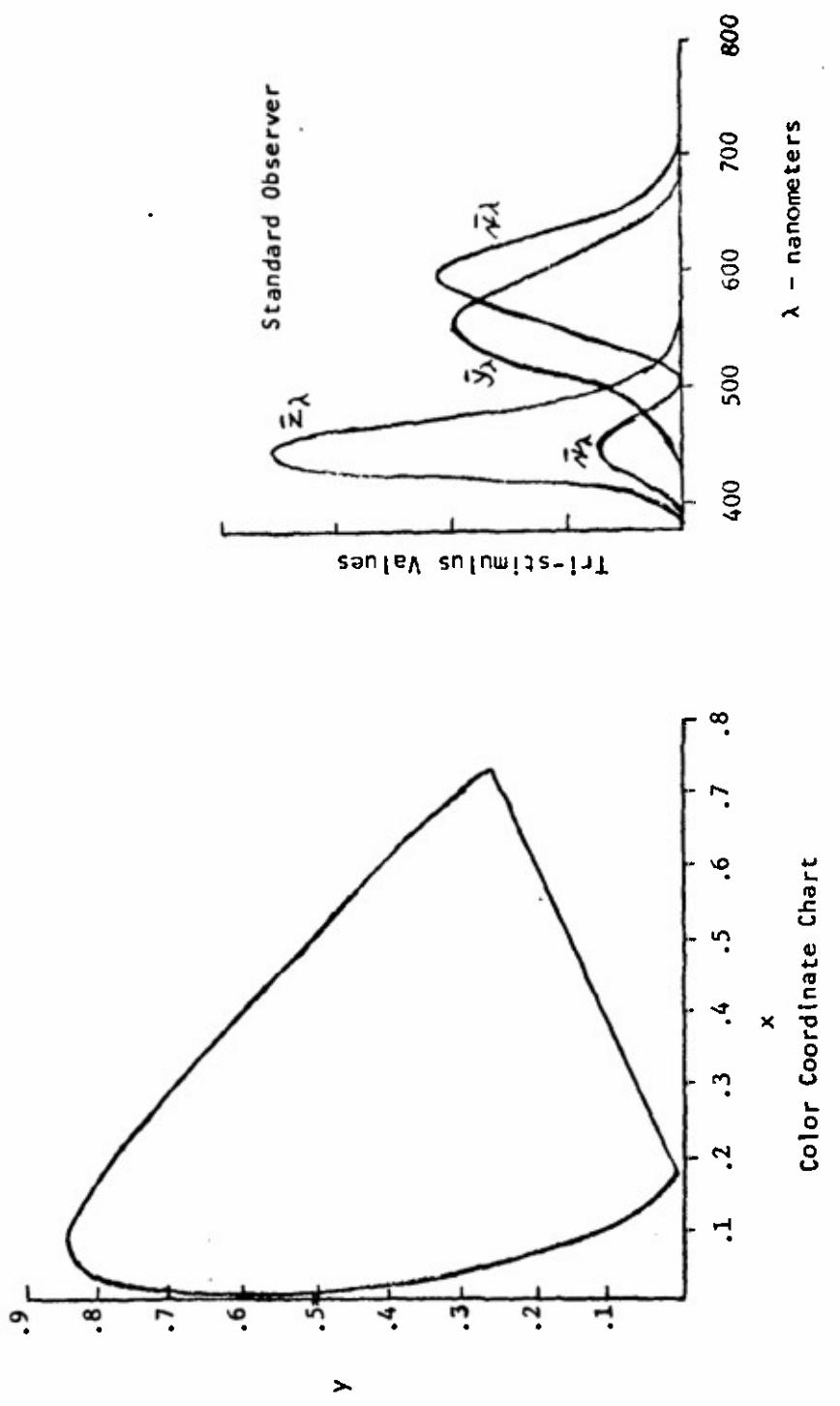


Figure A-3 CIE TRI-STIMULUS Commission International de l' Eclairage (1931)

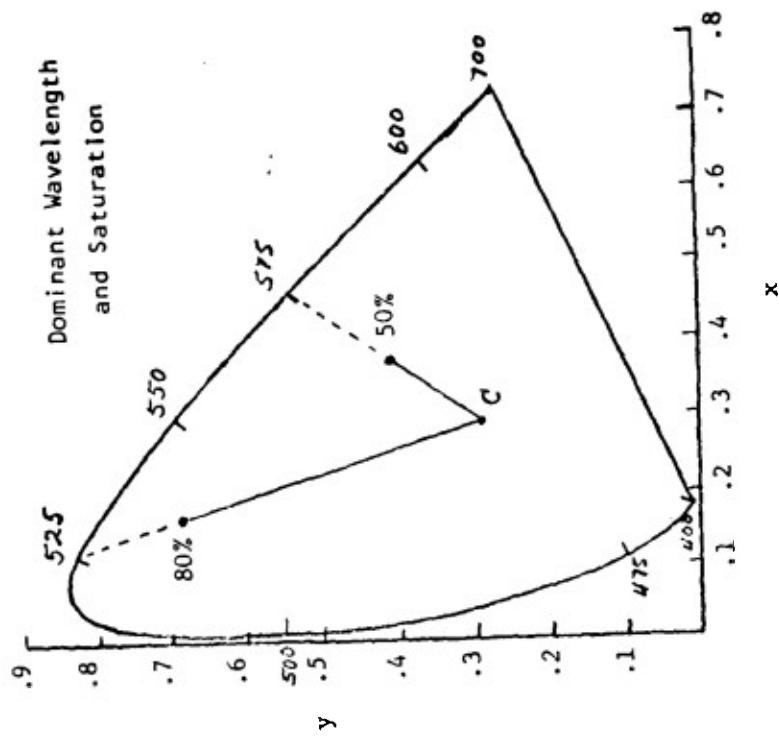
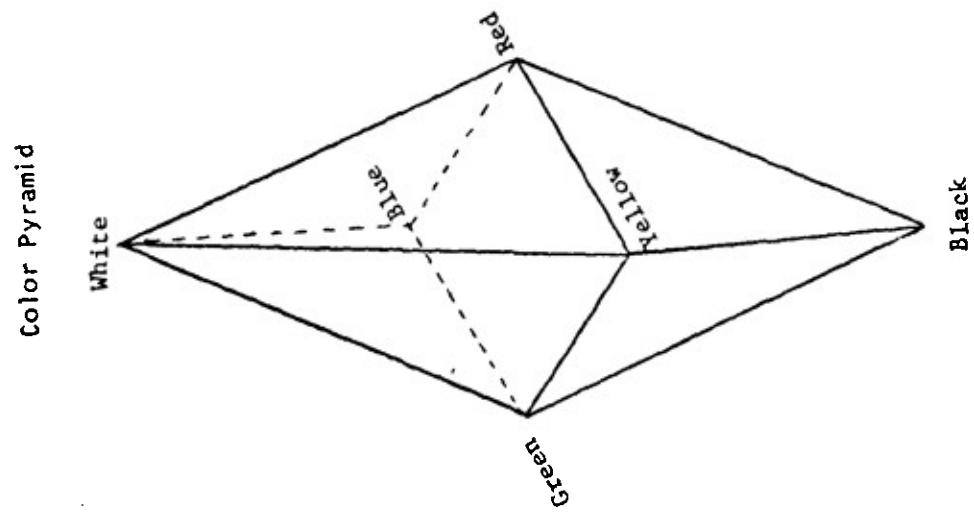


Figure A-4 Color Pyramid, Dominant Wavelength and Saturation

## IR Film

Cyan layer - red output - due to IR  
Magenta - green output - due to red-yellow  
Yellow - blue output - due to green blue filtered out by Wratten 12

Data accumulated to date includes the following:

### Sources:

Noon Sun - Standard Curve for Solar Constant  
Morning/Evening Sun - Published Literature  
Overcast Daylight - Published Literature

### Pigments

Natick  
Ferro Color Corp.  
Spectroradiometer - GE

### Backgrounds

Published Literature

### Detectors

Eye - CIE Normal Eye Response  
Color Film - Eastman Kodak  
IR Film - Eastman Kodak

The basic equations for spectral response are:

$$E_{\lambda} = B(\lambda) P(\lambda) D(\lambda)$$

$\lambda^2$

$$E = \sum_{\lambda} B(\lambda) P(\lambda) D(\lambda)$$

$\lambda$

E - watts/sq cm

$E_{\lambda}$  - watts/sq meter per 10 nanometers

$\Delta\lambda$  — 10 nanometers

$B(\lambda)$  — watts per sq. meter per 10 nanometers

$P(\lambda)$  — fractional reflectance

$D_e(\lambda)$  — (eye) — normalized response

$D(\lambda)$  — all film — fractional transmission

Data reduction and analysis to date include:

#### Computer

Calculated Response

Graphed Response

#### Interpretation of Numerical Data

Average Response by Sensor

Dominant Wavelength Bond

Relative IR Strength

#### Interpretation of Graphs

Eye Response

Significant Differences in Spectral Reflections

Visual Colors

Hue	Nominal Wavelength
Purplish Blue	475
Blue	483
Blue Green	491
Green	504
Greenish Yellow	565
Yellow	578
Yellowish Red	590
Red	650

Sample numerical data is as follows:

Variable Quantity	Pigment 1 379 Tan	Pigment 5 383 Black	Pigment 8 Dark Green
Average Response			
Eye	1.97	.24	.51
Color Film			
Cyan	23.3	2.6	5.2
Magenta	14.7	1.7	3.9
Yellow	40.9	5.9	8.8
IR Film			
Cyan	17.4	2.4	7.6
Magenta	28.1	3.2	6.3
Yellow	34.3	3.8	9.2

Figures A-5, A-6 and A-7 show computer outputs of the response of the Dark Green color in the 4-color personnel camouflage pattern vs wavelength to color film, IR film and the unaided eye. Figures A-8, A-9, and A-10 show the same information for a forest/green-grass background.

#### Dr. Robert Florentine — Physical Chemistry

We are able to identify color in terms of wavelength and spectral response. We are addressing ourselves to the extension of camouflage into the near infra-red. The pigments that are available and the patterns that are made from those pigments are designed to satisfy visual requirements as well as camouflage requirements. So far, people have concentrated on the visual factors. Once you put another requirement on it you find that although you might be receiving a good pattern in the visual colors you might find that in the IR photos its contrast with the background is tremendous. So the attempt here is to generate enough additional information on additional kinds of materials that could be incorporated into the systems that give good visual response and then extend those visual pigments into acceptable IR. So, what we have done is to look at a wide variety of the published data on the pigments and materials. We are showing that materials having wide variety of colors may be capable of a considerable contribution in the infra-red. If we concentrate in the IR response, we will have this additional option; we will be able to modify existing pigments for IR. From a chemical point of view we are trying to relate the kinds of reflectance to the chemical structure so that we can predict some

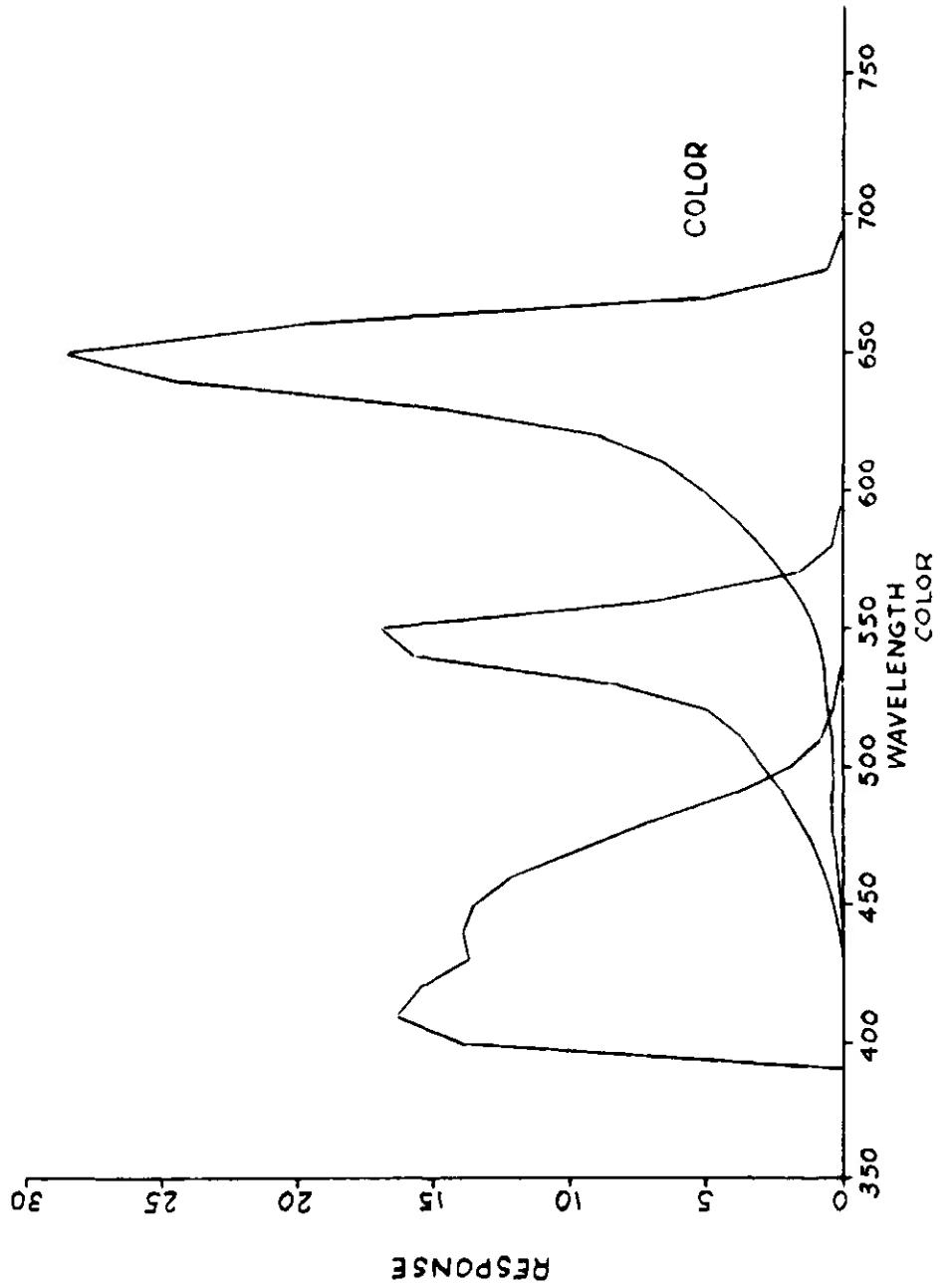


FIG. A-5 PIGMENT #8 4-COLOR DARK GREEN

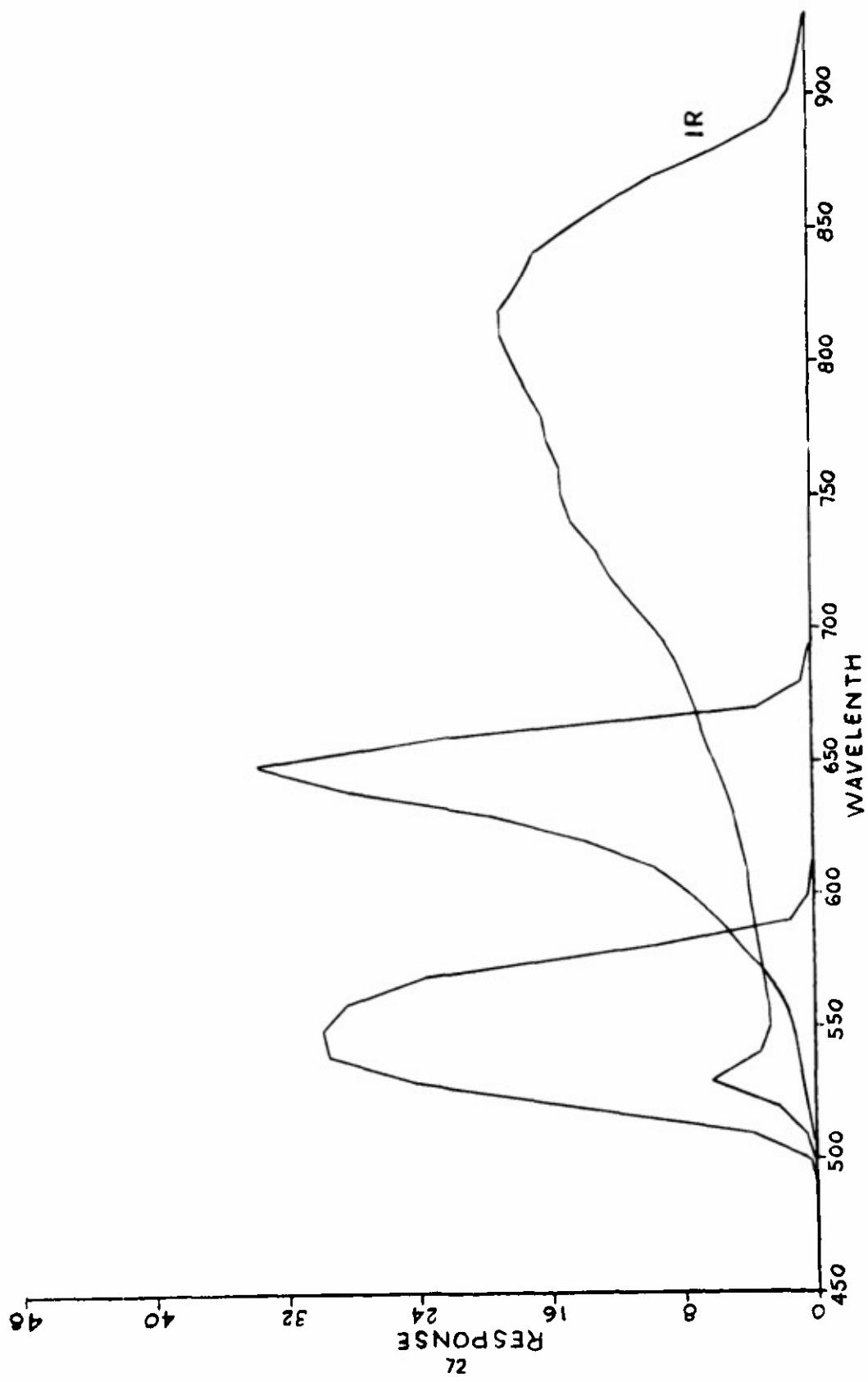


FIG. A-6 PIGMENT #8 4-COLOR DARK GREEN

-IR

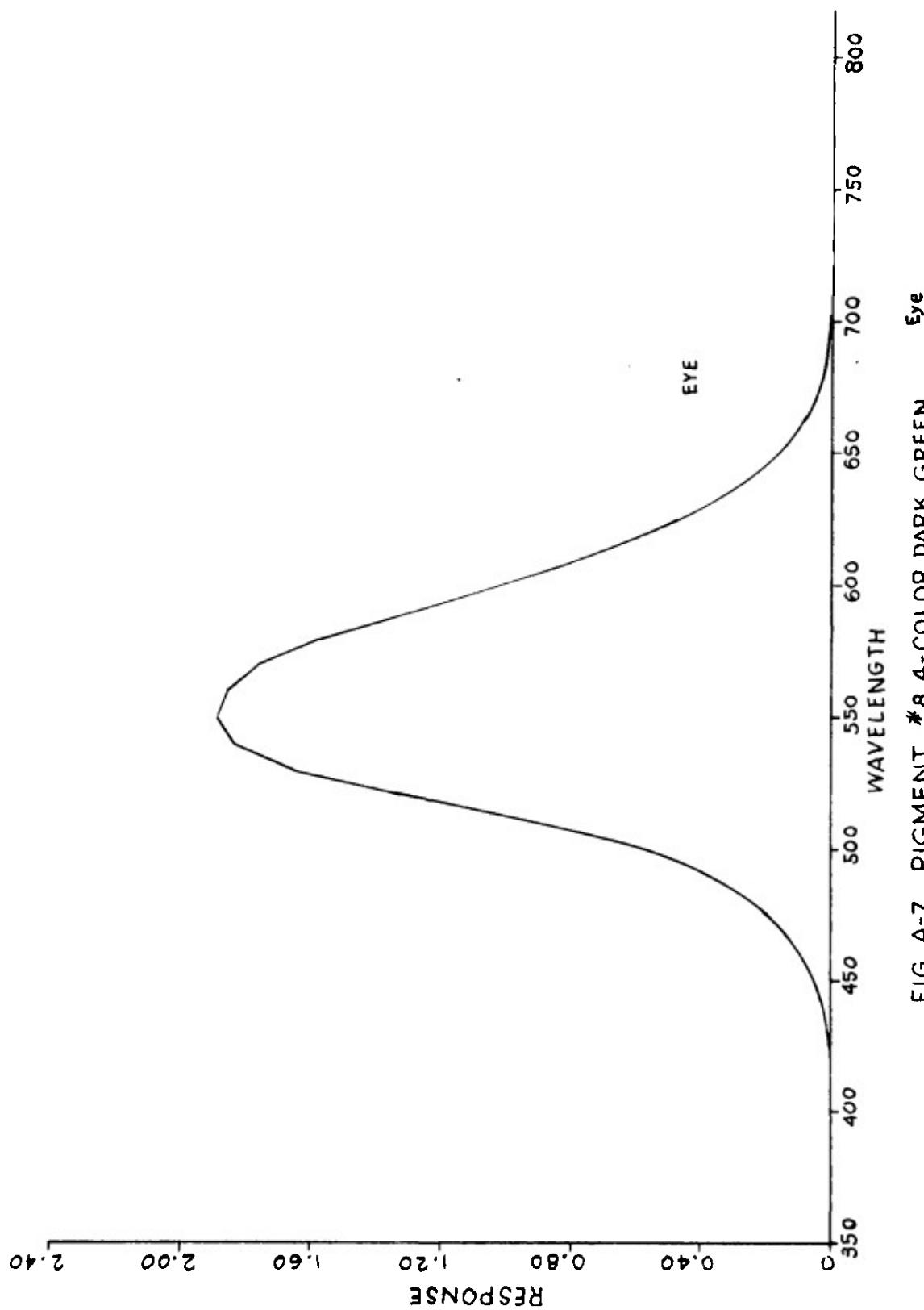


FIG. A-7 PIGMENT #8 4-COLOR DARK GREEN Eye

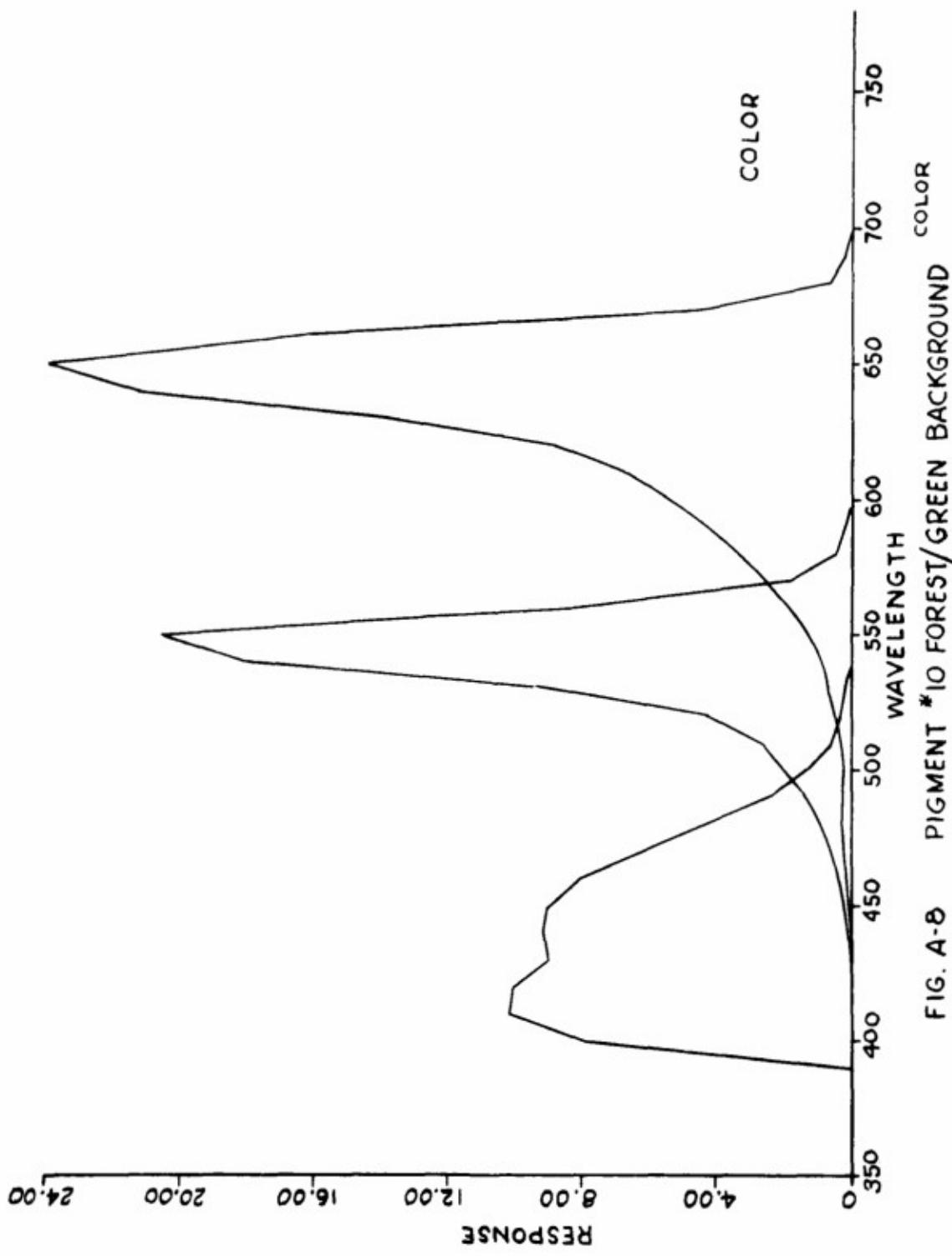


FIG. A-8 PIGMENT \*10 FOREST/GREEN BACKGROUND

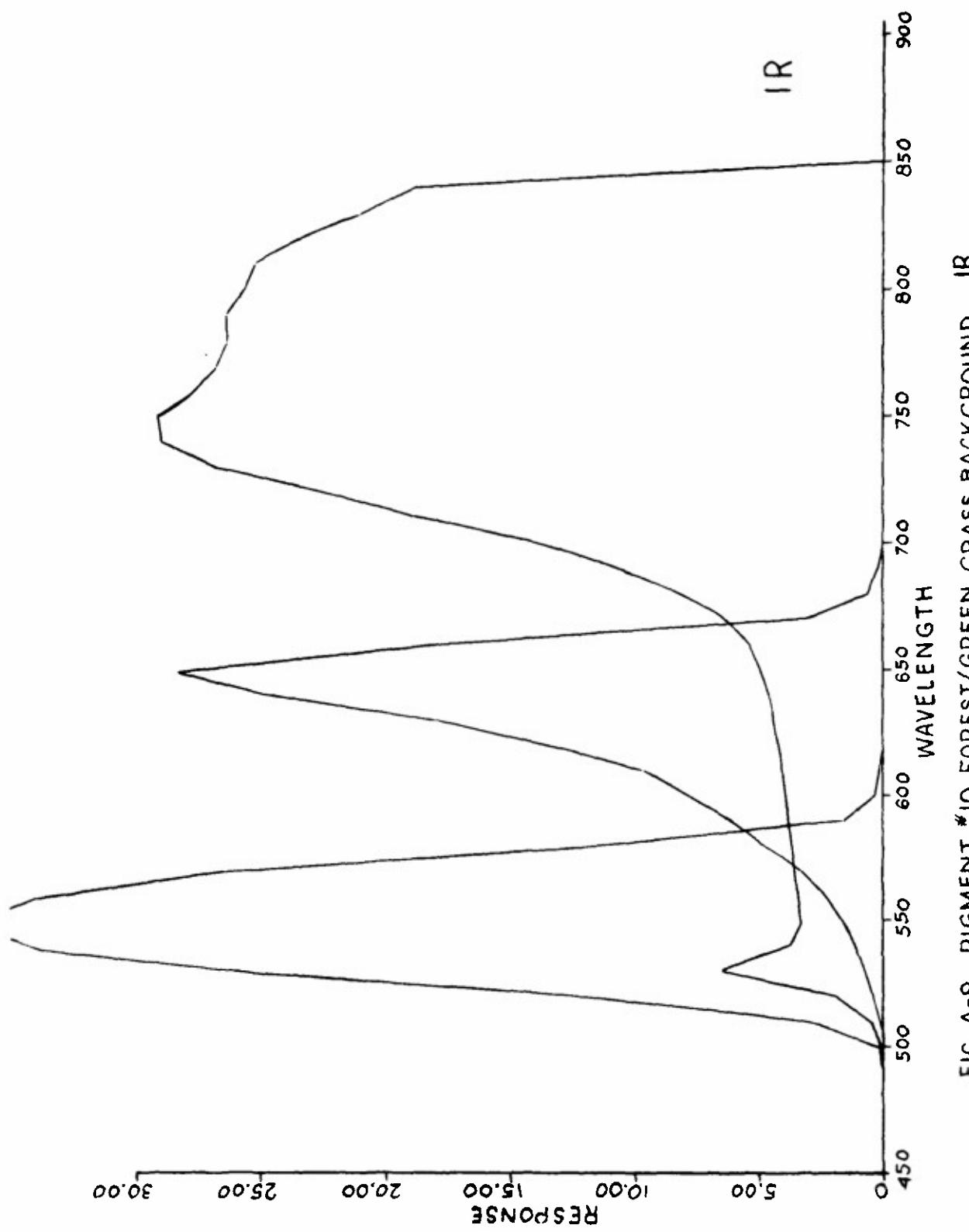


FIG. A-9 PIGMENT #10 FOREST/GREEN GRASS BACKGROUND IR

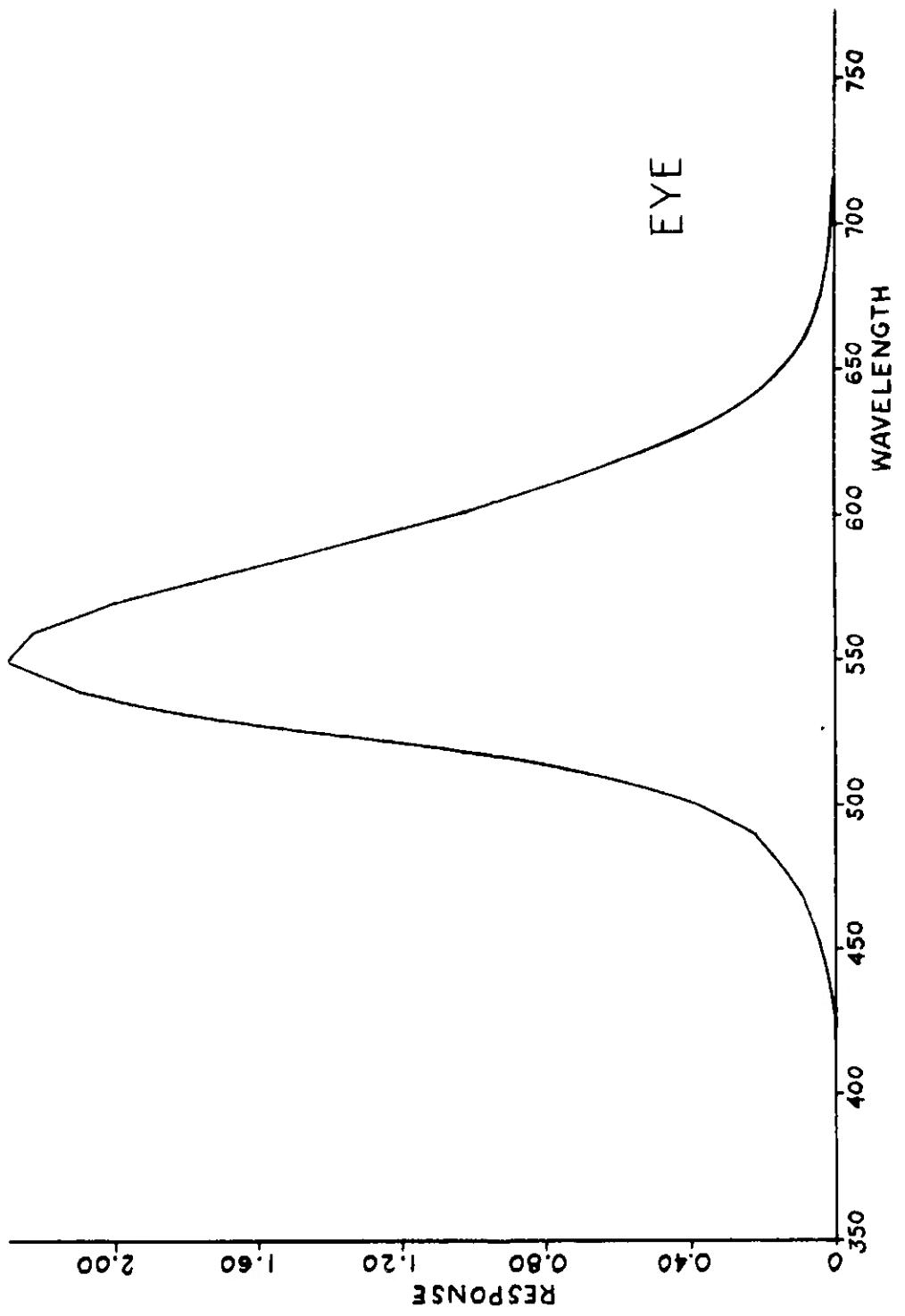


FIG. A-10 PIGMENT #10 FOREST/GREEN GRASS BACKGROUND

other materials which may make little contribution to the visible color but which may have a big effect on the IR region.

#### E. J. Dougherty - Pattern Design

This discussion will cover what has been done at FIRL in studying and developing patterns, and what may be done in the future.

While I am to be aware of the ultimate goals of applying a pattern to tents, my main assignment is to hide a tent at our test site. At the outset of the project, I studied the general concepts behind existing designs although I purposely didn't study the patterns themselves - the idea was to come up with an independent design.

I also studied the principles from our animal and insect camouflage study and I reviewed photographs of our test site. During these studies I made several sketches and some color paintings. In order to study the natural patterns in detail, and yet reduce the pattern to a paintable design, I devised a rear projection screen and displayed views of the test site. The rear projection system allowed me to trace the natural design. In the tracings, I quantitized the design into only five colors. The resultant patterns are much like a paint by number kit. After I had a pattern, I would juggle portions around a bit to take advantage of the camouflage design principles. For example, a branch pattern would be placed across a vent flap to cause a deceptive disruption.

Having a pattern, the next problem is evaluation of the pattern. It's difficult to paint a whole new tent to try out various patterns and modifications. Therefore, I developed methods to model and simulate a camouflaged tent in various field situations. Again using the rear projection screen and masking out tent shapes, I made paintings of the pattern and attached time to the screen. With this I could see how various patterns would look at our test site. By simply pushing a button I could change the location, the time of day, or the weather conditions.

The other evaluation method I used was similar but added another dimension. I made models of the tents, applied patterns to them and placed them in front of the rear projection screen. Using the models we also plan to do some sun angle studies.

The next phase of the evaluation was to make up lifesize strips as a convenient way to try out candidate patterns on the tents in the field.

Up until now, I've been studying backgrounds fairly close, 200 m (200 yds) and, therefore, fine patterns. I will study some long range views which will result in large pattern size. I would predict that the final product will be a combination of both types of patterns - fine detail up close, blending into larger color areas when viewed from a distance.

The methods we are using for visually designing and evaluating a pattern are effective, but they could be improved. As an engineer, I can see several areas of improvement as I will now present.

I would like a library compiled of typical scenes in which tents may be present. Compiling this photographic almanac would be quite a task, but would provide a good data base. For example, the photos could be used in a method similar to my present method: using rear projection slides with a pattern; the simulated tent could be transported to any location under various environmental conditions. A further step would be to computerize the system by accessing particular types of scenes, for example, desert, midday. You could look at a scene from morning until night, using time lapse photography, see the same scene for several days at the same time of day, etc.

The actual development of patterns from natural surroundings could be automated. For example, a system could be devised similar to the method used to convert photographs to paint by number sets.

Also, using the data base and quantizing it, a computer could come up with an average pattern for various situations.

I think a computer could very well aid in pattern design by speeding up the design, evaluation and modification process. Using a computer TV display I could draw with a light pen the basic pattern, assign colors to the pattern, calling up from memory the background photos (from the compiled photographic library). The designed pattern could be superimposed on the background pattern. At the operator's direction the pattern could be moved, enlarged, reduced, reproduced, modified (shape and color). The background could also be modified. In this way an ideal visual pattern could quickly be designed and evaluated in a simulated field situation. This may sound far out, but aside from the library of backgrounds, many industries use techniques very similar to this, for example, advertising layouts.

#### Fred Fortress - FWWMR Protection

Our job is very simple and very complex. The objective is to camouflage 10,000 tents. We must accomplish this without undoing any of the important properties of the FWWMR coating (FIRE RESISTANCE, WATER RESISTANCE, WEATHER RESISTANCE and MILDEW RESISTANCE) and superimpose upon this a pigmented pattern that will be difficult to detect in visible, black and white, and I.R. photography. We are caught somewhere between the physicist and the artist, our approach is empirical. As you heard earlier, given 5 years or so, computers are going to make the job of designing camouflage in the laboratory very easy. This ultimately is the way to proceed. Our present manual methods of spraying and cutting out stencils are empirical but are the only way we can perform under the contract's time and money limitations.

We are responsible for developing formulations to protect the FWWMR that is now in the fabric. With respect to the superimposition of the pigmented binder, we are using polyvinyl chloride. Having looked through all of the military documents, we have chosen the simplest approach by taking the dry finish formulation. It is primarily a polyvinyl chloride chlorinated paraffin formulation. To the two materials we have added, for protection, a stabilizer, for elasticity a plasticizer (i.e., tricresyl phosphate). The tri-cresyl-phosphate may also contribute to the anti-flame properties. Antimony oxide is an anti-after-flame material and is also used as a dulling agent to help to cut down on the gloss properties. The pigments have been used by Natick and their IR values are known. However, I have not decided whether or not we want a balanced reflectance. I would like to see some holes in the pattern to agree with what we have seen in the field tests.

Our really big problem is definition of terrain. Right now we are working for the summer-tree line type environment. In reality some definition is needed as to the type of backgrounds we are to deal with. Example, in early spring we'll see lots of tree trunks, while in mid-July we see only leaves and holes.

Protecting the FWWMR is easy, our present formula will do fine; it has been checked, in fact it even has anti-tack properties — it will not stick together when folded. The real problem is pattern and translating from mock-ups to regular commercial scale production in terms of salvaging the existing medium and small tents.

#### **Betsy Damos — Application Techniques**

I'm concerned with how to apply the colorant to the tent surface. It would be a great deal easier if we were printing, a pattern on material prior to construction of the tent. This printing could be standard printing methods such as screen-printing, roller printing, rotary screen printing, etc. I decided that a flexible stencil would be best for the present program. Flexible because it would have to cling to the contours of a tent. A stencil was cut for color and a spray gun was used to apply the colorant. The first stencils were made of a poly-vinyl chloride, this worked but didn't have the endurance we require. In the future, we will use a 100% polyester stencil or perhaps canvas. The application may require that the tents be knocked down and the sides stretched one at a time. The alternative to spraying is to apply the colorant with brushes; we will avoid this if possible.

Our present formula evaporated very quickly during spraying so that it actually dried before hitting the tent surface. Modifications will be made in the formulation to avoid this characteristic in the future. We also discovered using the standard air spray gun that the material should ideally be in a vertical position. The frequency of the gun clogging was increased as the material approached horizontal. We also concluded that the simpler the pattern the easier the application.

## General Discussion

The conference was culminated with a general discussion which lasted two-and-a-half hours.

Colonel Kieghler kicked off the discussion by showing slides of camouflage he had from Ft. Hood. Comments in response to these slides and the following discussion pertinent to our objectives included:

### Slides

Note distinct differences in terrains. Ft. Hood, for instance has much more brown.

Vehicle surfaces are prepared prior to painting. Pattern is then "eyeballed on" with chalk. (Magic Marker works better). Color areas are then identified by number and paint is sprayed on. Sloppy edges are not a problem.

Airless spray gun would eliminate need for stencil.

Colors in slide are not good representation.

Nets are needed to break up edge.

Barbed wire is used on periphery. It stands out vividly.

Type of terrain can compromise an otherwise good pattern.

Tent deployment is important.

Oft-times you can be camouflaged from one direction and exposed to another.

Zebra type patterns may be good for open terrain.

Europeans do not have so much undergrowth. Forests are tall and open around the base of the trees.

Shadows are problems with vehicle.

Sometimes, "internal" shadows help to break up form.

Low flying helicopters pick out antennas easily.

Some work is being done on remote antennas (relocate to tree, for instance).

Nets look good. Dark green is good. Open nets allow some light through for good effect.

Reversible tent is probably answer for the future.

Vehicle tracks are major problems. The U.S. is not proficient in this area.

Tracked Vehicle: pattern for wheel is no good because wheels never stop in the right place.

Door left open on vehicle can look like big rectangular black area.

Advantage of four-color MERDC pattern is that two of the colors can easily be changed.

Perhaps we can just give the field soldier a pattern. Let him decide on colors.

Change sand into field drab could make the difference between earthy vs foliated tree line areas.

If you survive the first look, your chances of survival are greatly enhanced.

#### Discussion

Emphasize vertical lines at base of tent.

At roof line, emphasize lines generally perpendicular to the edge.

Look at enlarging personnel pattern more.

Consider "patterns within patterns" such that as you go further and further away, the patterns blend into larger units.

Maintain ability to customize camouflage.

Have tents you can reverse or turn inside out.

Personnel pattern looked good along ridge of tent. Vertical portion allowed it to blend into background.

Consider spray gun application - not aerosol can. Aerosol cans get clogged and they don't hold large enough volumes.

Desert areas have lower vegetation.

Can count on setting tent up adjacent to some foliage or large rocks but don't rely on tree lines being available.

Don't paint each side of tent for different background because sometimes you would have to, in effect, rotate it 90°. "Inside out" is a good concept. Changing color is good.

Since you can only camouflage by painting, consider optimum pattern obtainable and content that further cover can only be derived by nets.

Greatest detection threat is from air. Shadow is biggest give away to photos. Colors alone cannot solve the overall problem.

IR black and white is best camouflage detection film.

Define distance of detection.

Surveillance is recognition.

Reconnaissance is a closer look.

Good infantry moves twice daily. Once in daylight, once at night. By the time enemy studies film, we are gone. Protect us from visual aerial acquisition and from reconnaissance patrols with access to artillery.

Evaluation at MASSTER are on a subjective basis.

Night vision using starlight scopes will probably not change the problem.

Rule of thumb regarding patterns leaving the upper edges perpendicular to the surface is probably not a good general rule.

MASSTER would be interested in instruments to make objective comparisons.

Goals should include brightness, gloss and distance effects.

MERDC has computer program to design paints and to evaluate reflectivity.

Rain compromises camouflage.

Swedes use plastic nets.

Don't add too much weight (spraying will minimize weight).

Density (number) of tents in an area is major consideration.

Track extenders are used in forward areas.

U.S. Army Imagery Interpretation Center can be of help to us (Jim Selecta - Evaluation and Analysis Division, Fort Holabird, MD.)

Look at B&W IR film.

MERDC is having a pattern design class.

#### Debriefing

Program redirection dictated by the results of this conference includes the following:

Visit Army Imagery lab

Visit MERDC

Supply MERDC with tent painted with MERDC pattern and four gallons of paint by the third week in August (Note: This decision was later modified due to results of conference at MERDC).

Supply 30 cm<sup>2</sup> (1 ft<sup>2</sup>) samples of FWWMR-treated duck in each of the four colors.

Use paint pressure spray gun (Note: This was also modified by MERDC because this type of gun necessitates a different compressor.)

Get color chips from MERDC.

Invite Ferro Corp. to visit FIRL.

Use tricresyl phosphate in formula.

Optimize formulations.

Review MERDC computer capabilities.

Continue to study new compounds for their IR properties.

Write and distribute conference report.

Conduct flame and water tests.

## **APPENDIX B**

### **FIELD APPLICATION TECHNIQUES AND PATTERN SCHEMES**

**John A. DeBenedictis  
Dr. Constantin J. Monago**

**The Franklin Institute  
Research Laboratory  
Benjamin Franklin Parkway  
Philadelphia, PA**

**December 1974**

## APPENDIX B

### FIELD APPLICATION TECHNIQUES AND PATTERN SCHEMES

#### **FIELD APPLICATION TECHNIQUES**

This section deals with the list of materials required for applying the camouflage color, preparation of the tent, and application guidelines List of Materials:

- Tent made from FWWMR treated canvas
- Camouflage Overcolorant, Black (B)
- Camouflage Overcolorant, Field Drab (FD)
- Camouflage Overcolorant, Dark Green (DG)
- Camouflage Overcolorant, Sand (S)
- Methyl Ethyl Ketone (MEK)
- Spray gun complete with air supply
- Mask with independent air supply (Air tanks)
- Paint brush (3" - 5" width)
- Paint mixing device (power or manual)
- 6-foot rule
- Lime striker
- Chalk
- Rags
- Lift (e.g., cherry picker, fork lift with cage, etc.)
- Gloves

#### **Preparation**

The FWWMR fabric must be clean, dry, and field worthy. Overcolorants should be thoroughly mixed. Spray equipment must be clean and free of residuals which may interfere with an even spray.

#### **Application Guidelines**

Procedure for sketching the pattern.

The tent is laid out on a relatively flat surface such that the aerial view is facing upward. Fig. B-1 shows the aerial view. Each section is then subdivided by measuring half the distance from section border to section border and striking a line with the line striker. (Lines are shown dashed on Fig. B-1). This procedure is repeated for each section and each direction. The seams of the tent are used as section borders. The pattern\* is then drawn on the tent with chalk in a free hand manner using the square sections

\*Tent patterns are shown on Figures B5 through B29

as guides. Note that the lines drawn on the tent surface should also be drawn on the paper depicting the tent pattern for clarity. Each section may be subdivided again should the technician desire more detail but one should keep in mind that variations of less than 2.5 cm to 5 cm (1 to 2 in.) are imperceivable at the expected observation ranges. The same procedure is used for the sides, ends, and for different tents.

#### Pattern Application

Pattern lines are guides to the painter. Slight overlapping of colors is acceptable. Overcolorants should be applied in thin layers. Avoid "running" of colors or excessive build-up which will result in gloss. Covering should be sufficient to hide the base color of the fabric.

Apply the colors in the following order:

- 1 Black (B)
- 2 Dark Green (DG)
- 3 Field Drab (FD)
- 4 Sand (S)

Keep in mind that camouflage is designed to afford protection from distances of hundreds of meters. Slight imperfections or incomplete covering of pattern outlines are of no concern. These conditions are not detectable beyond 20 or 30 meters (22 or 33 yards).

Tent guidelines should be thoroughly covered with a random pattern. At least two overcolorants (and no more than three) should be used on each guyline. The minimum length of a pattern on a line is 30 cm (one ft).

Flaps and tiedowns must be painted on undersurfaces as well as top surfaces.

#### PATTERNS

Figures B-1 through B-29 are a complete set of drawings for the GP medium and the GP small tents. The Nature, Zebra and Personnel (10x) patterns are presented in detail. Drawings for the MERDC pattern are available from "Camouflage Pattern Paintings-Design Drawings-Appendix B" USA MERDC, Ft. Belvoir, VA.

Figure B-2 shows an aerial view of the GP medium tent. Figures B-3 and B-4 show the side and end views respectively.

Figures B-5 through B-9 show the nature pattern applied to all aspects of the GP medium tent. The legend is as follows:

B - Black  
FD - Field Drab  
DG - Dark Green  
S - Sand

Note that each side of the tent is labelled with a letter: A, B, C or D. This is for orientation purposes. The pattern varies slightly for each side and each end. This was done to allow an evaluation of variations. For instance, Fig. B-6 shows side A of the nature pattern. Fig. B-7 shows side B. Note that side A has a preponderance of horizontally slanted designs. Each segment is relatively large. Side B emphasizes vertical strokes and smaller segments. This scheme allows the evaluation to compare effectiveness and select the best design. On the other hand, if the evaluation fails to detect a significant difference, one can conclude that minor variations are irrelevant.

Figures B-10 through B-14 presents the same information for the zebra pattern. Note again, for instance, the difference between B-11 and B-12. B-11 shows vertically oriented lines while B-12 tends toward the vertical but is much more varied.

Figures B-15 through B-17 presents the same data for the personnel pattern. Since this pattern is a copy of a final design, it is symmetrical. The labelling of the sides is shown only for clarity and consistency. Note that the sides are interchangeable.

Figures B-18 through B-29 presents the same information for the GP small tents.

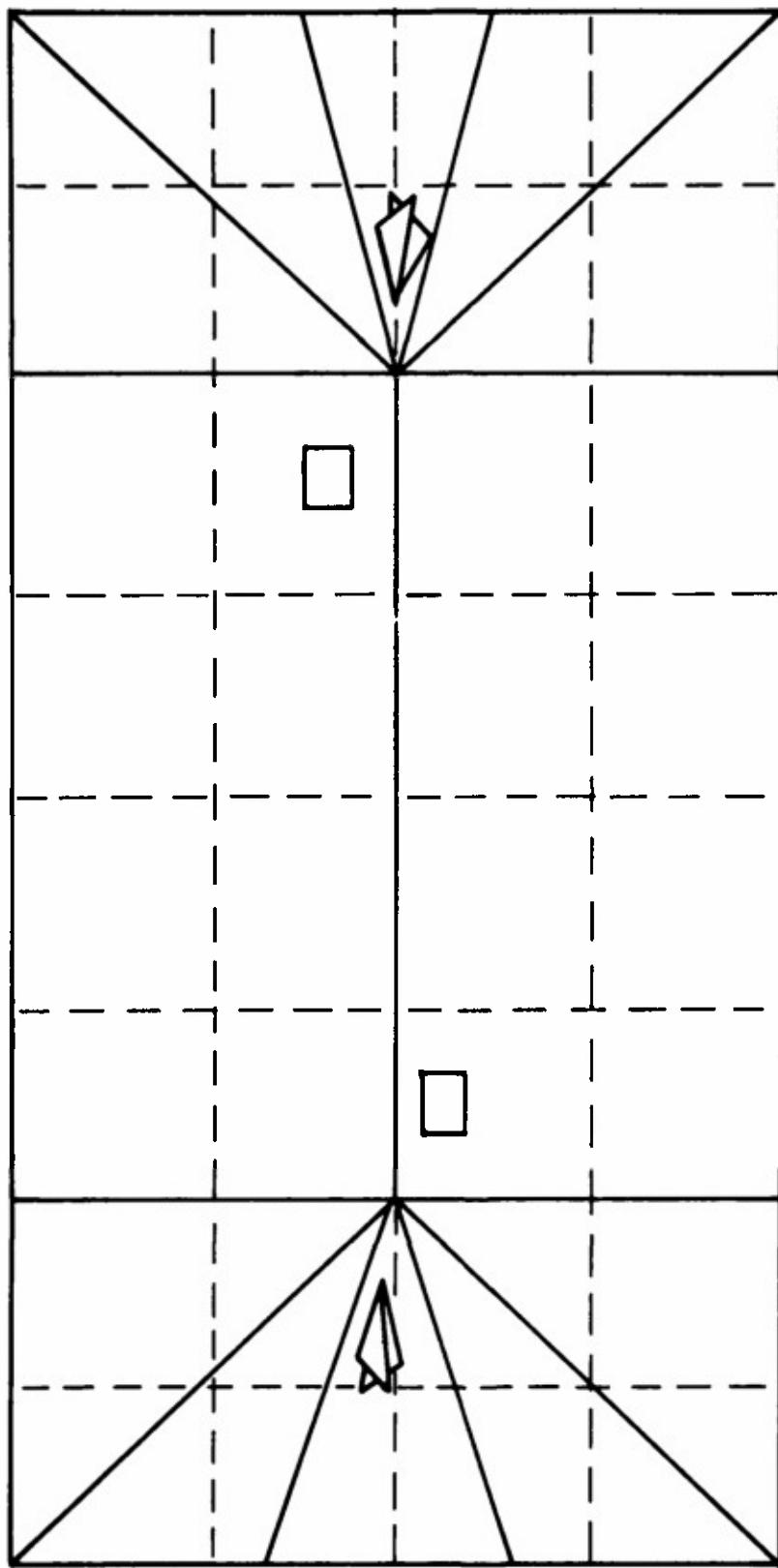


Figure B- 1. Field Application Technique

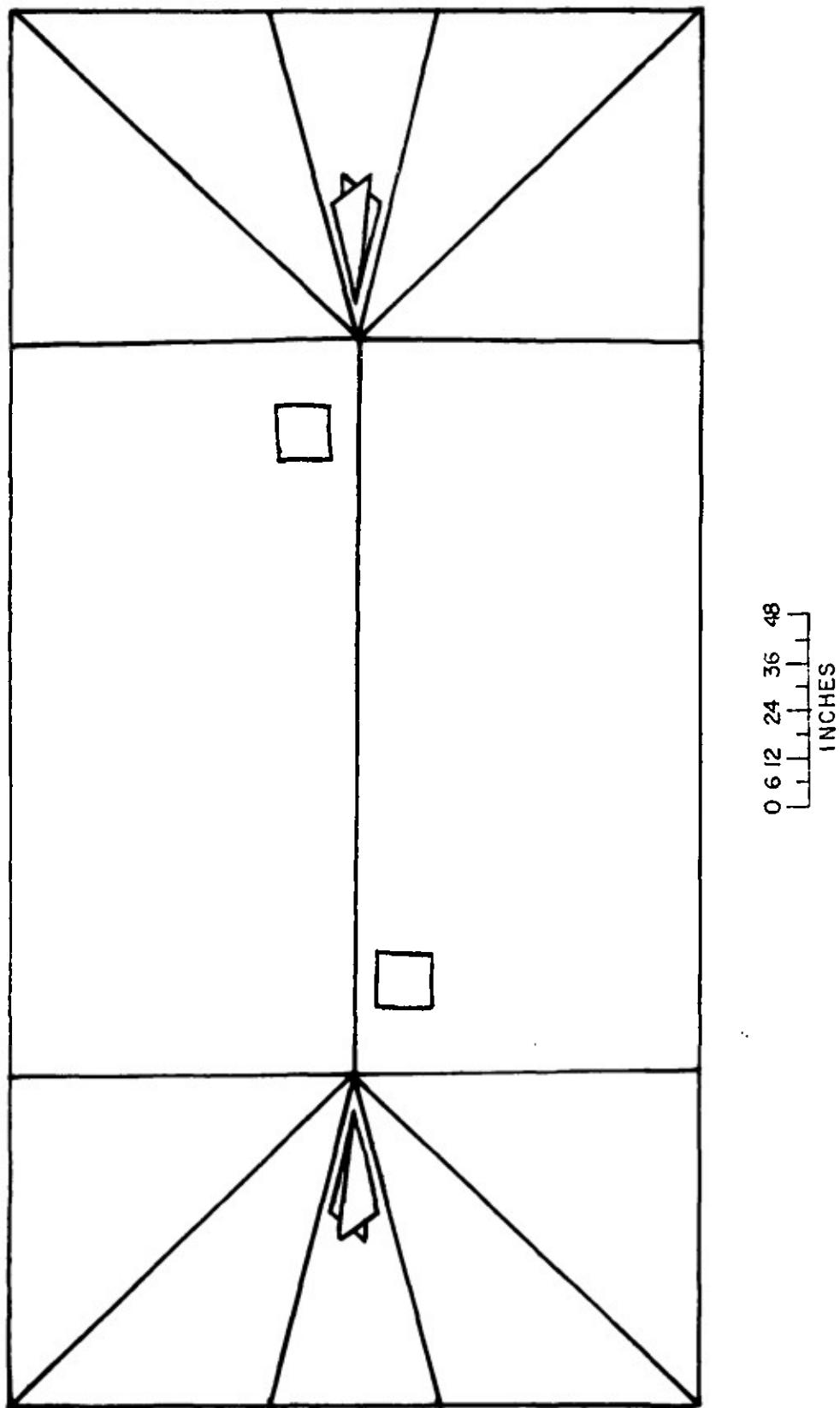


Figure B-2. Top View - G.P. Medium

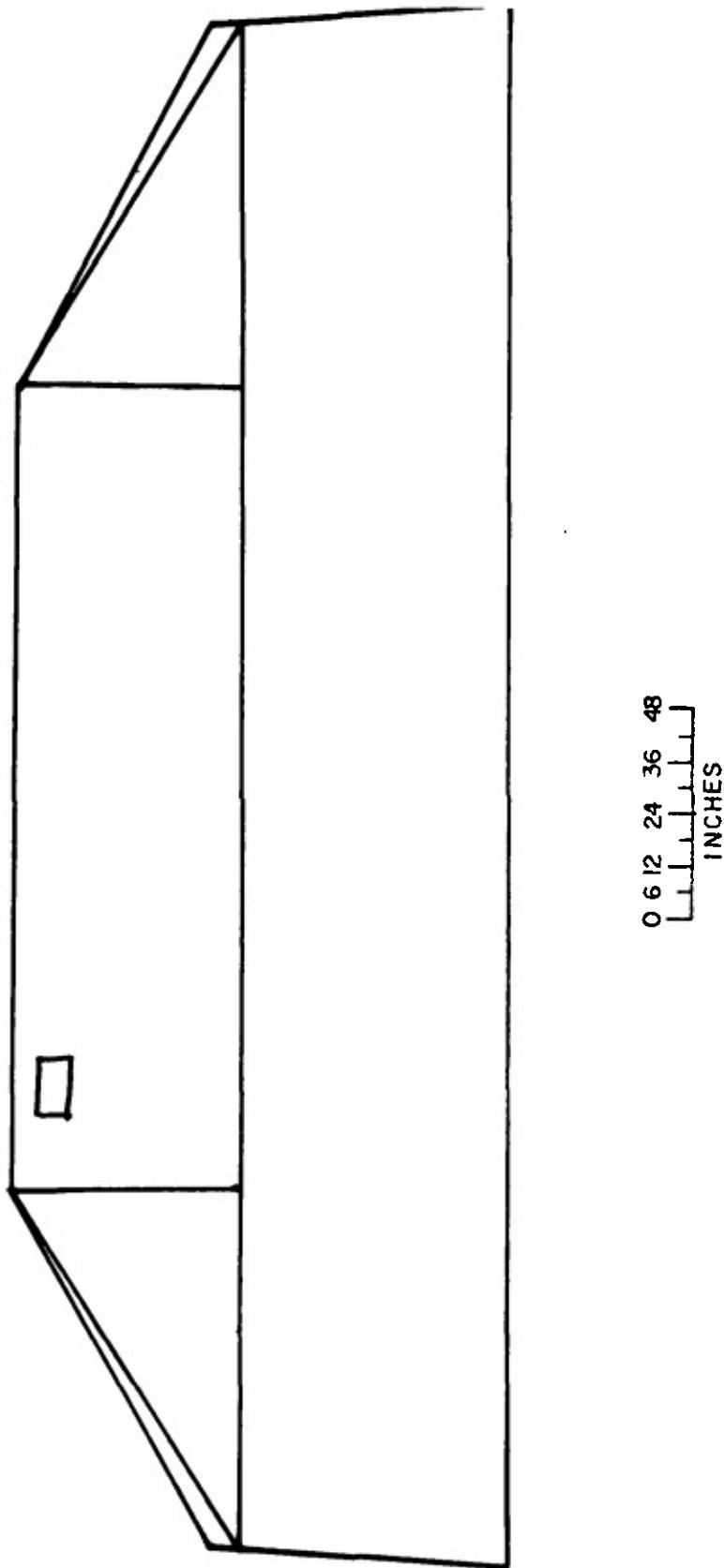


Figure B-3. Side View - G.P. Medium

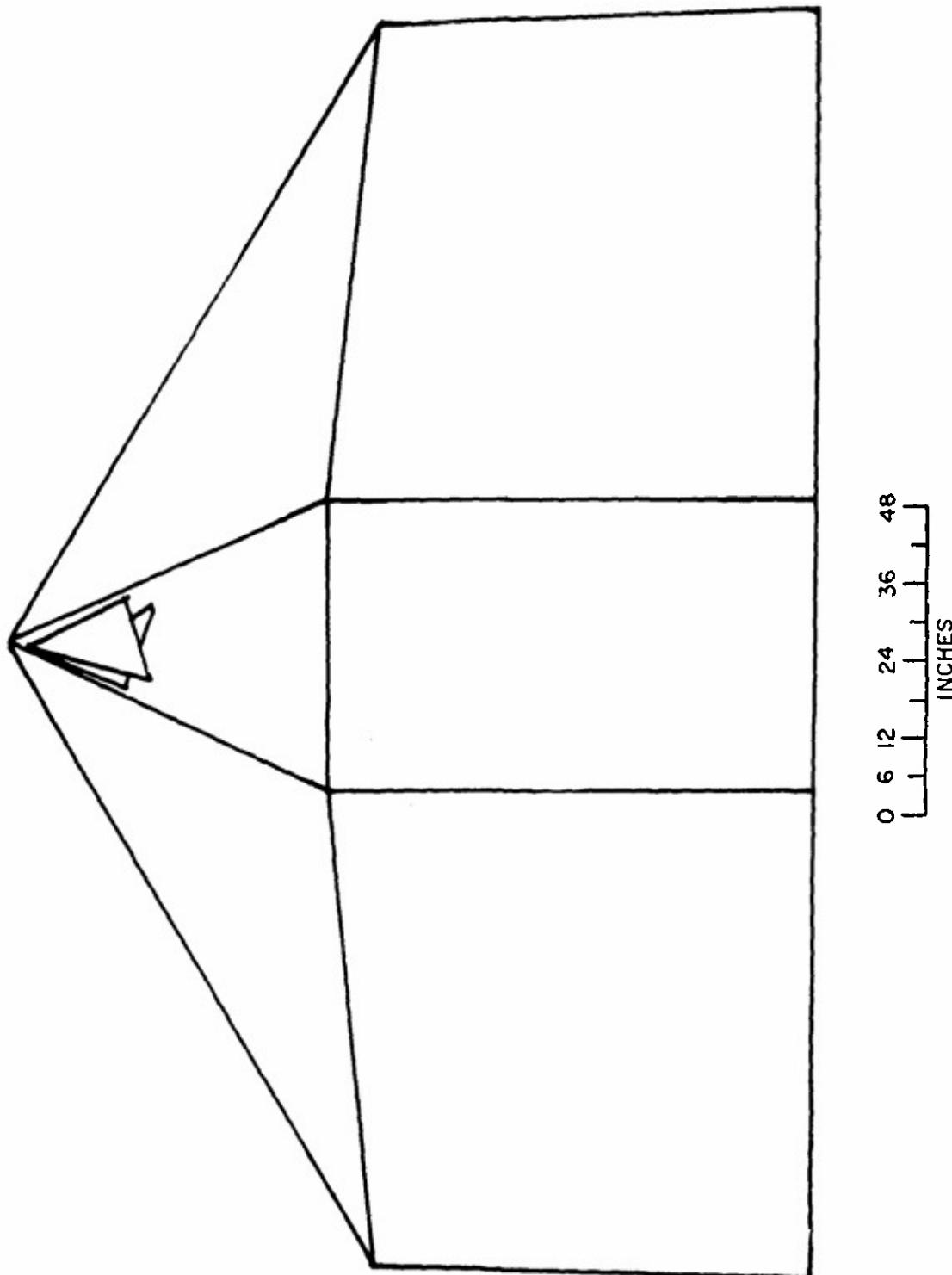


Figure B-4. End View - G.P. Medium

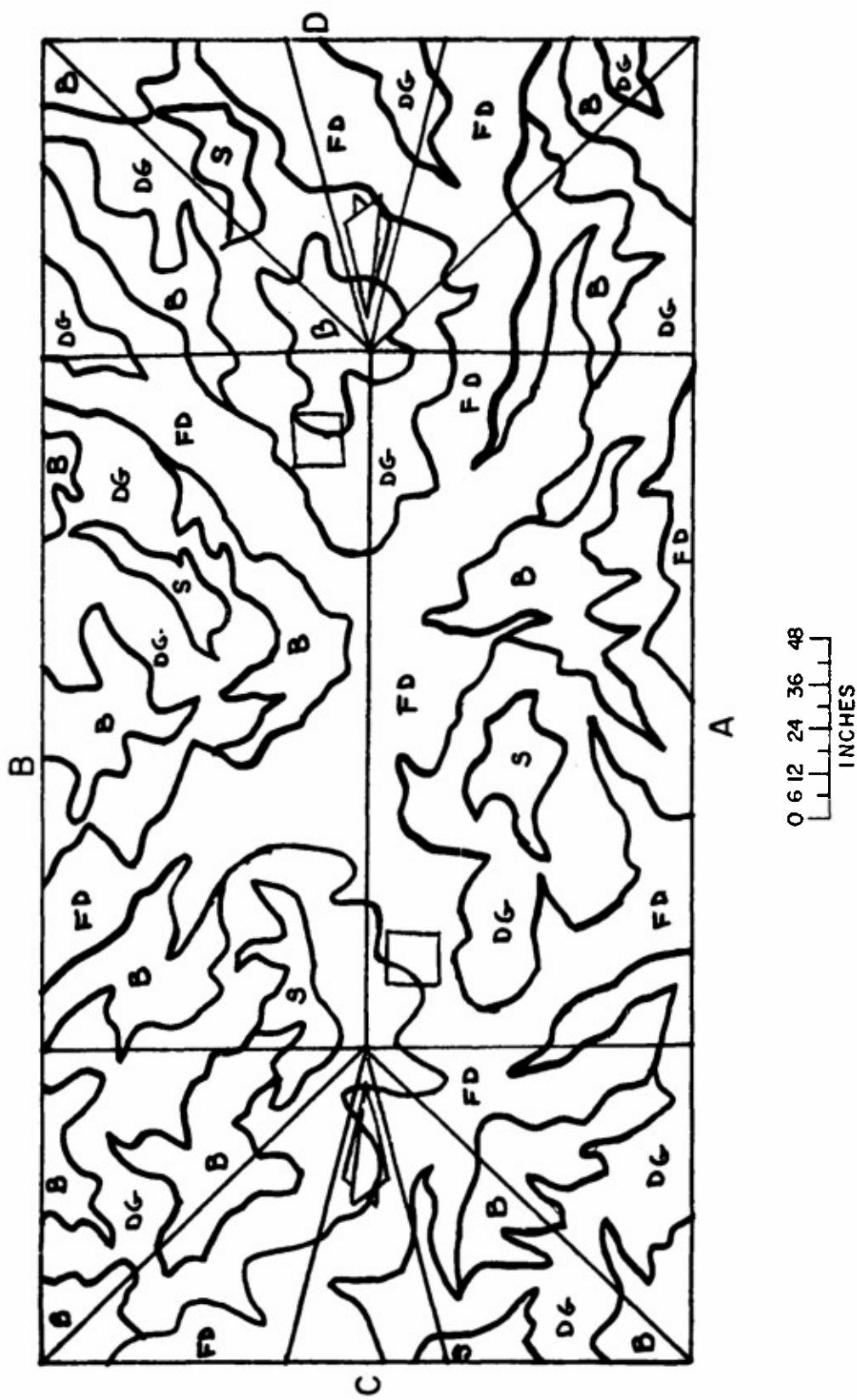


Figure B-5. Nature Pattern - Top View - G.P. Medium

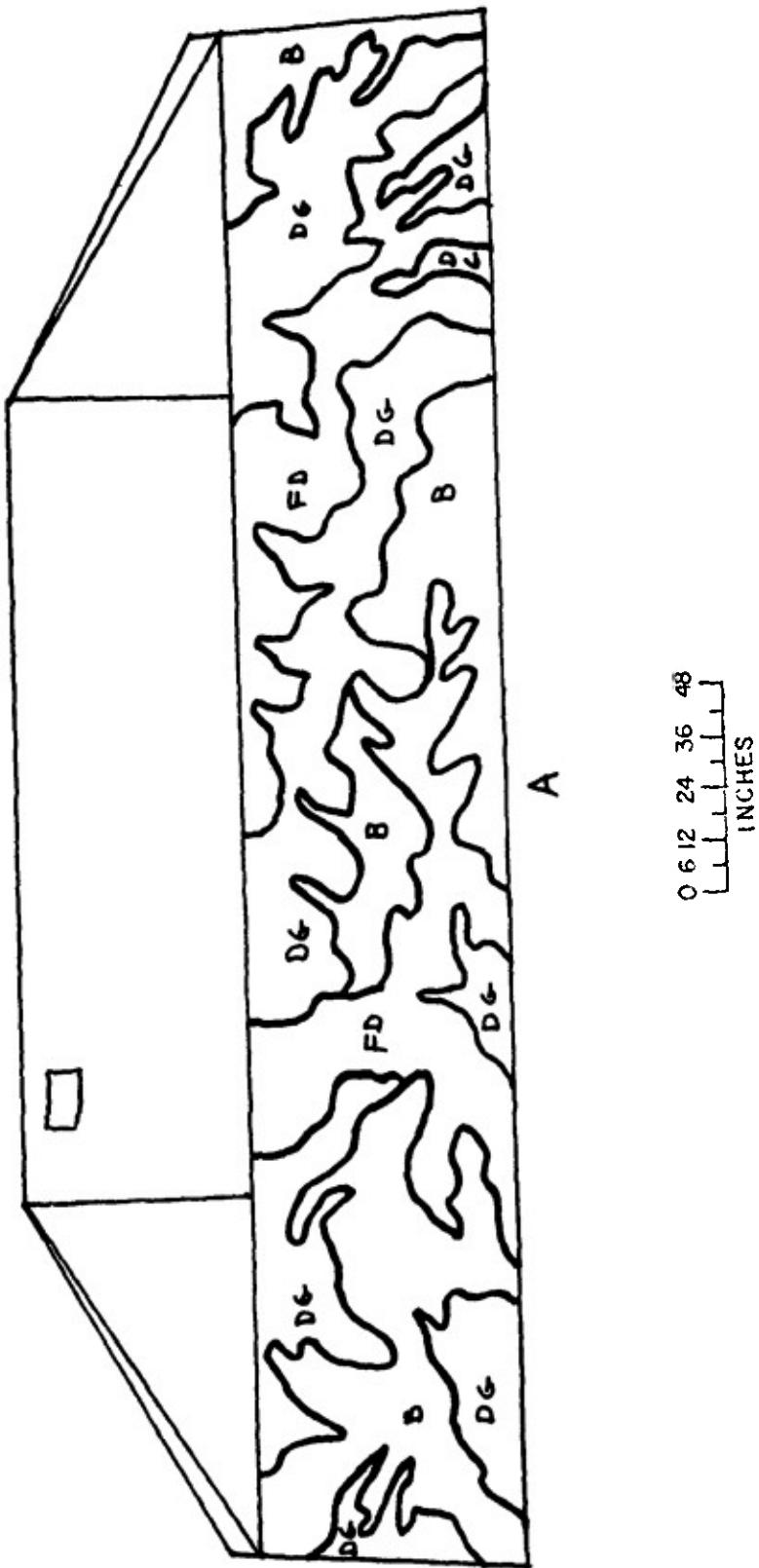


Figure B-11. Nature Pattern - Side A - G.P. Medium

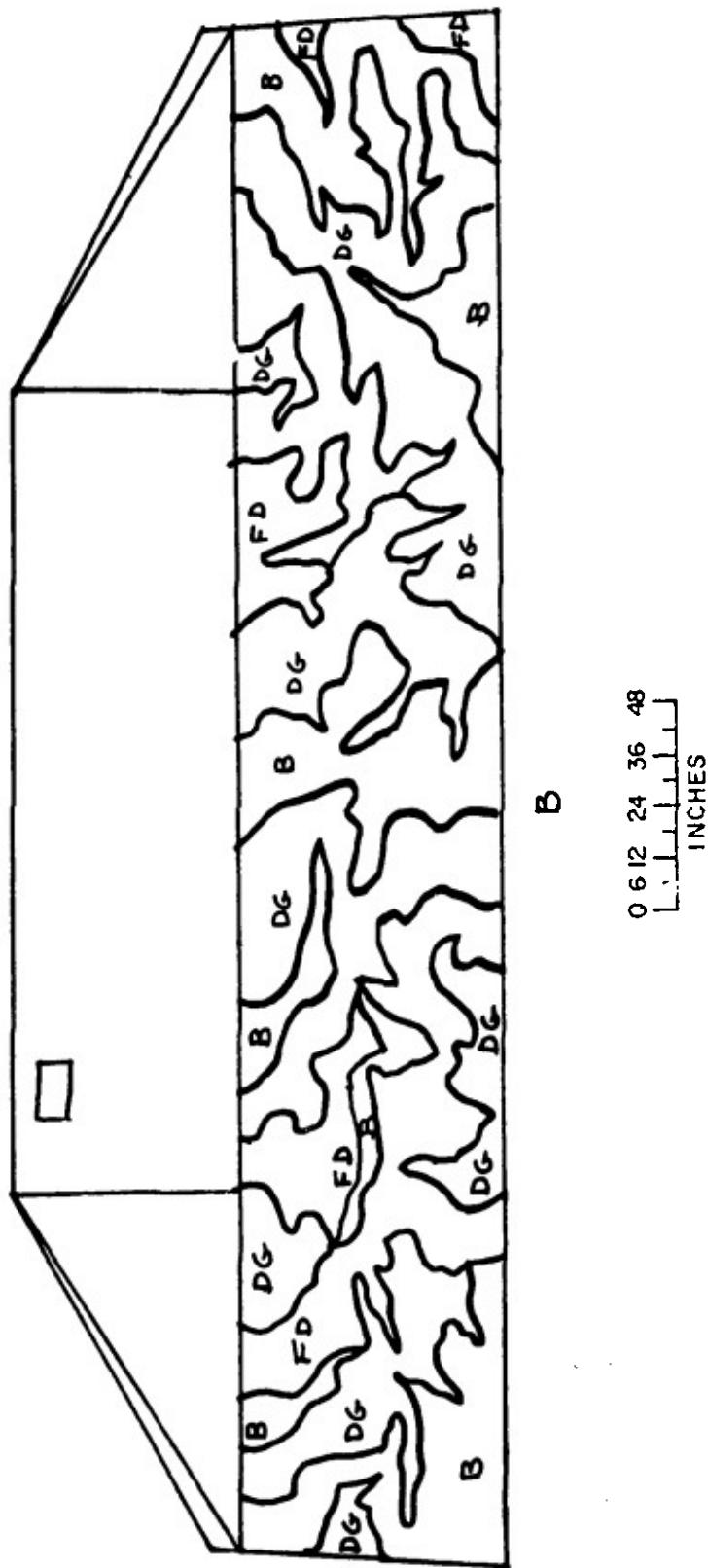


Figure B-7. Nature Pattern - Side B - G.P. Medium

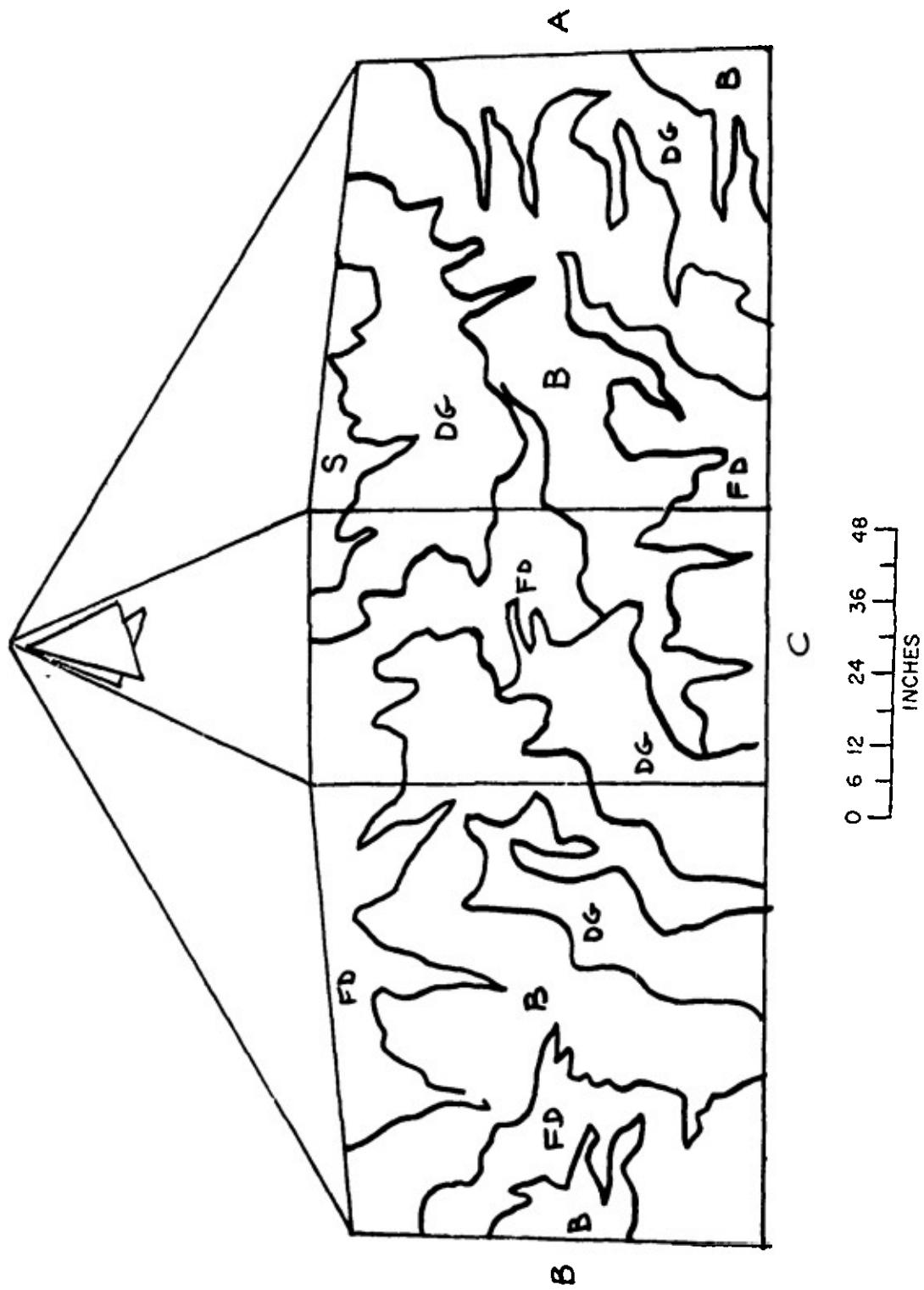


Figure B-8. Nature Pattern - End C View - G.P. Medium

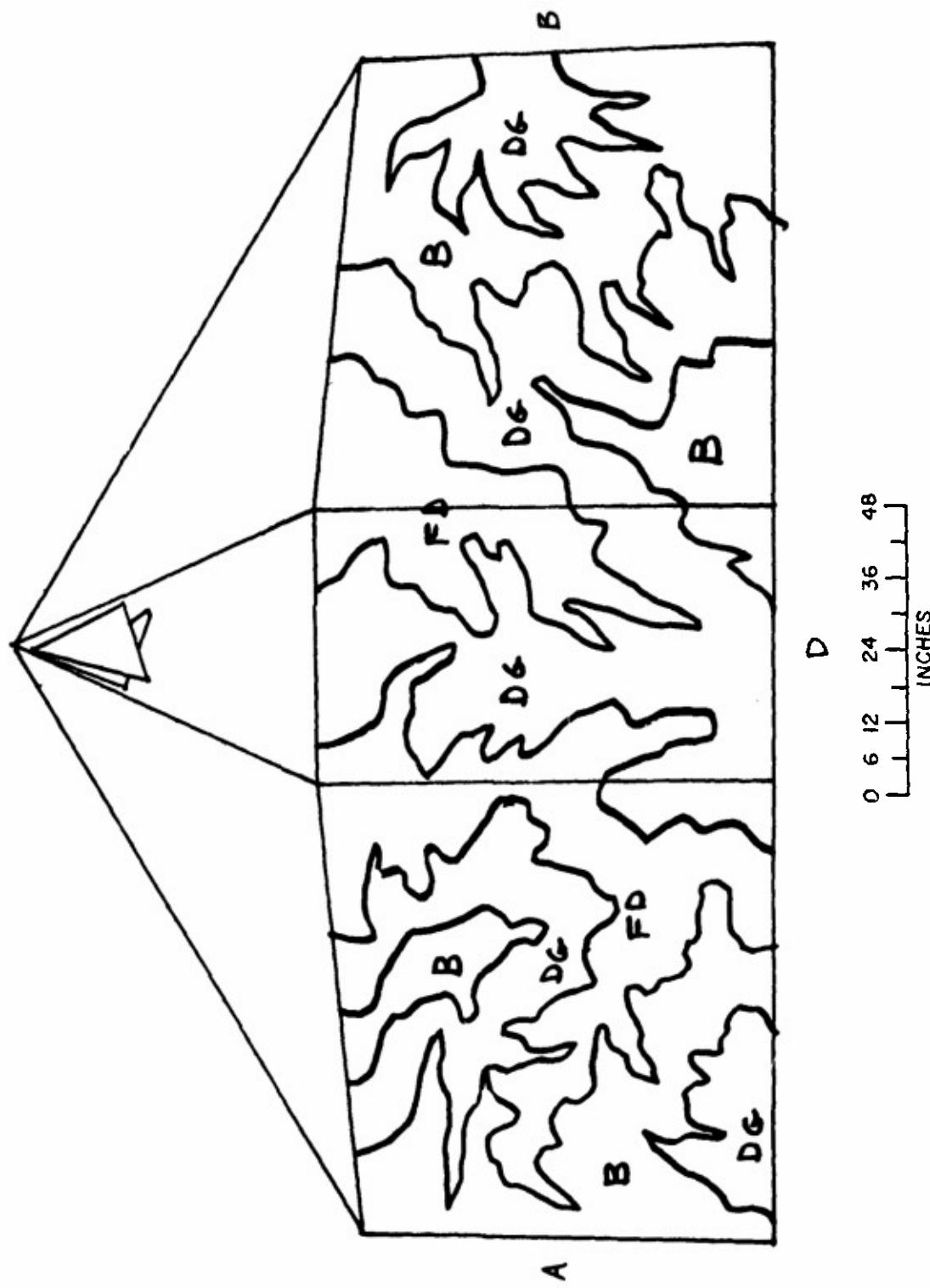


Figure B-2. Nature Pattern - End D View - G.P. Medium

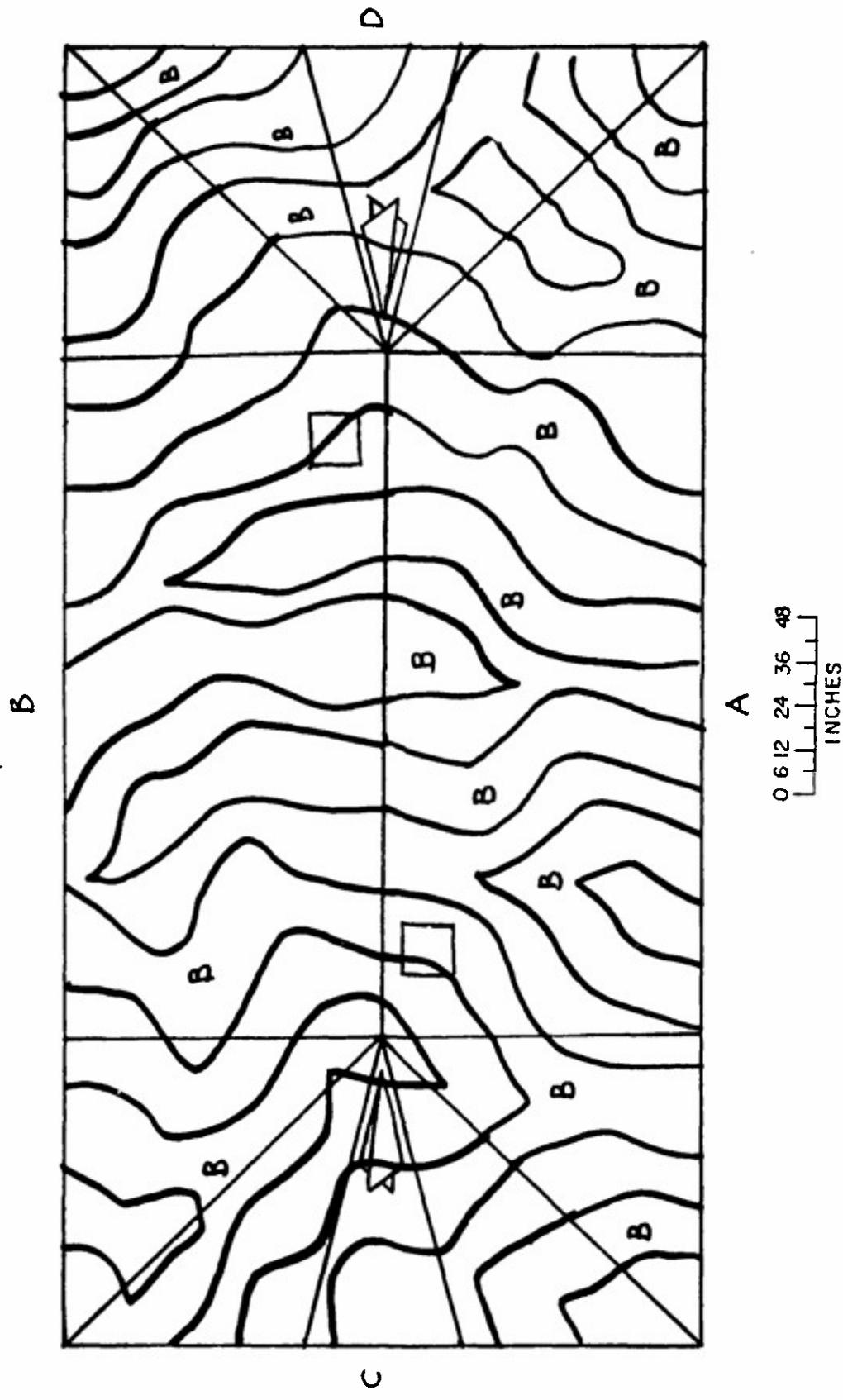


Figure B-10. Zebra Pattern - Top View - G.P. Medium

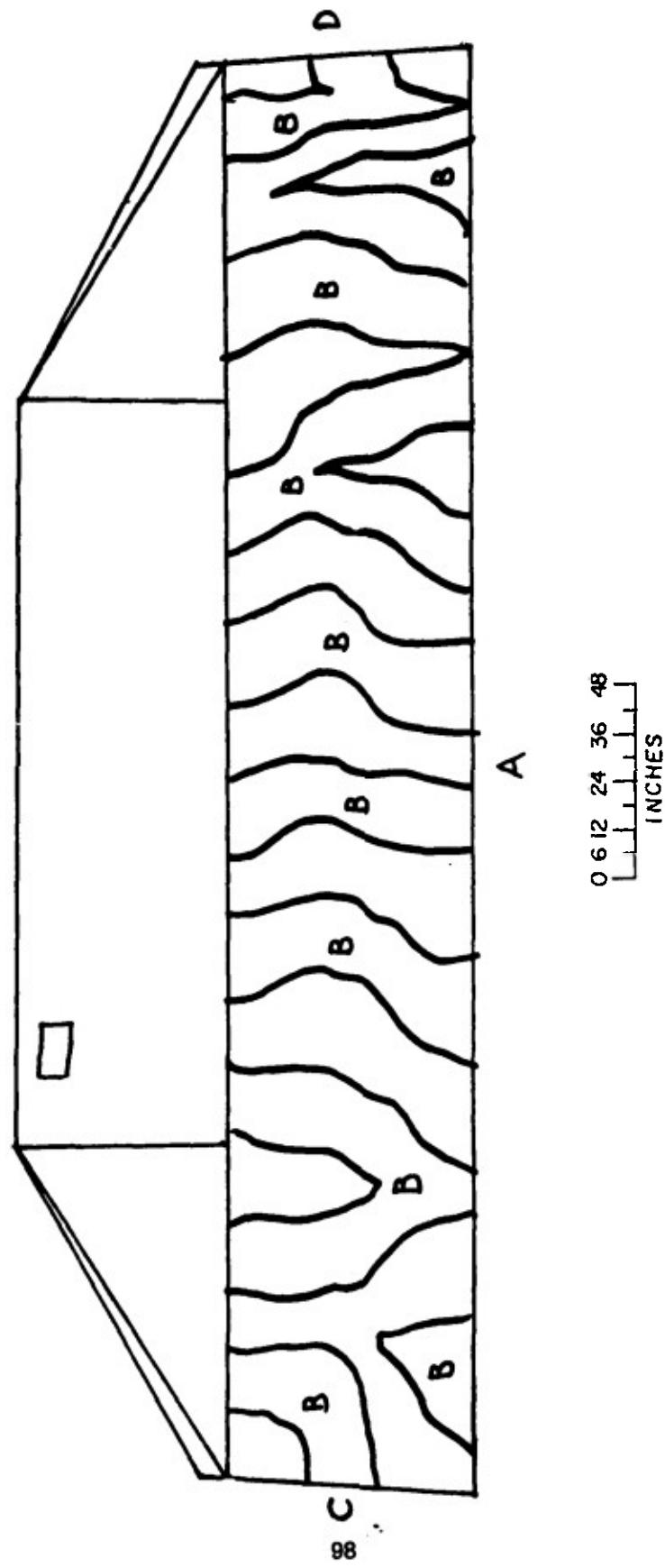


Figure B-1L. Zebra Pattern - Side A - G.P. Medium

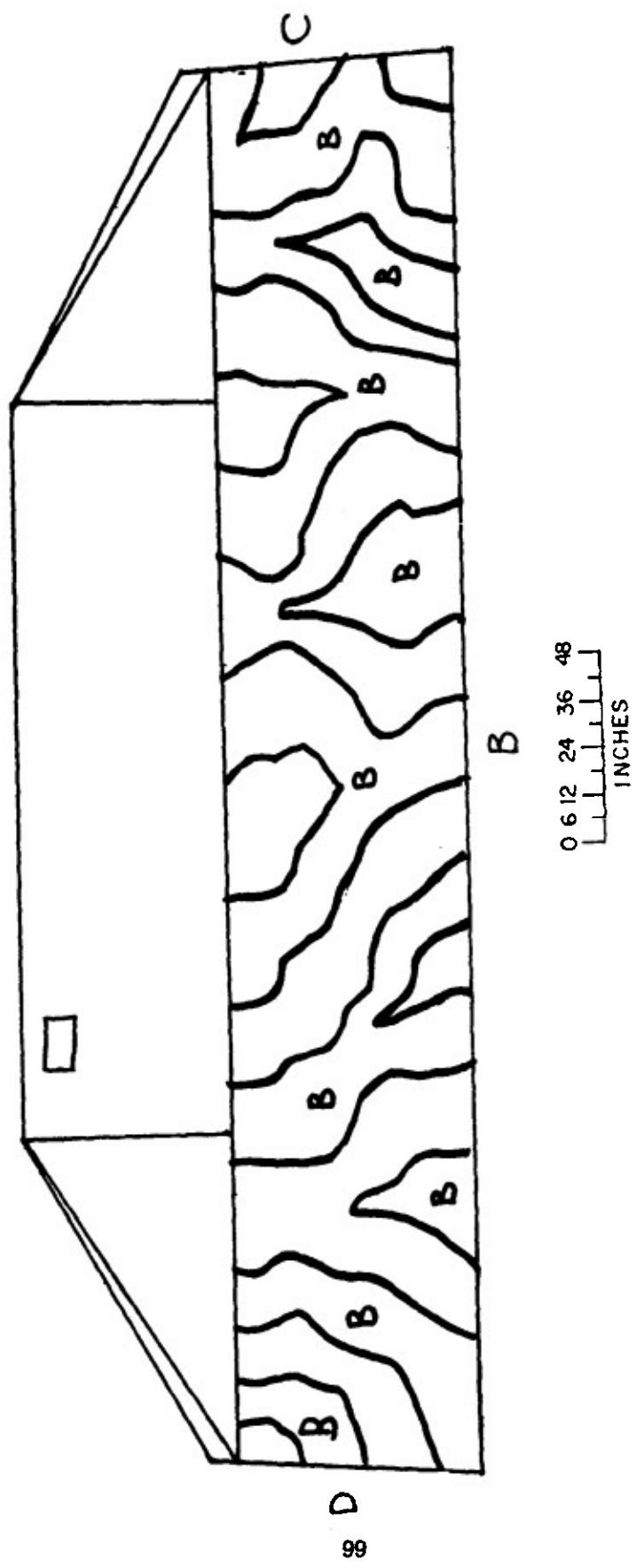


Figure B-12. Zebra Pattern - Side B - G.P. Medium

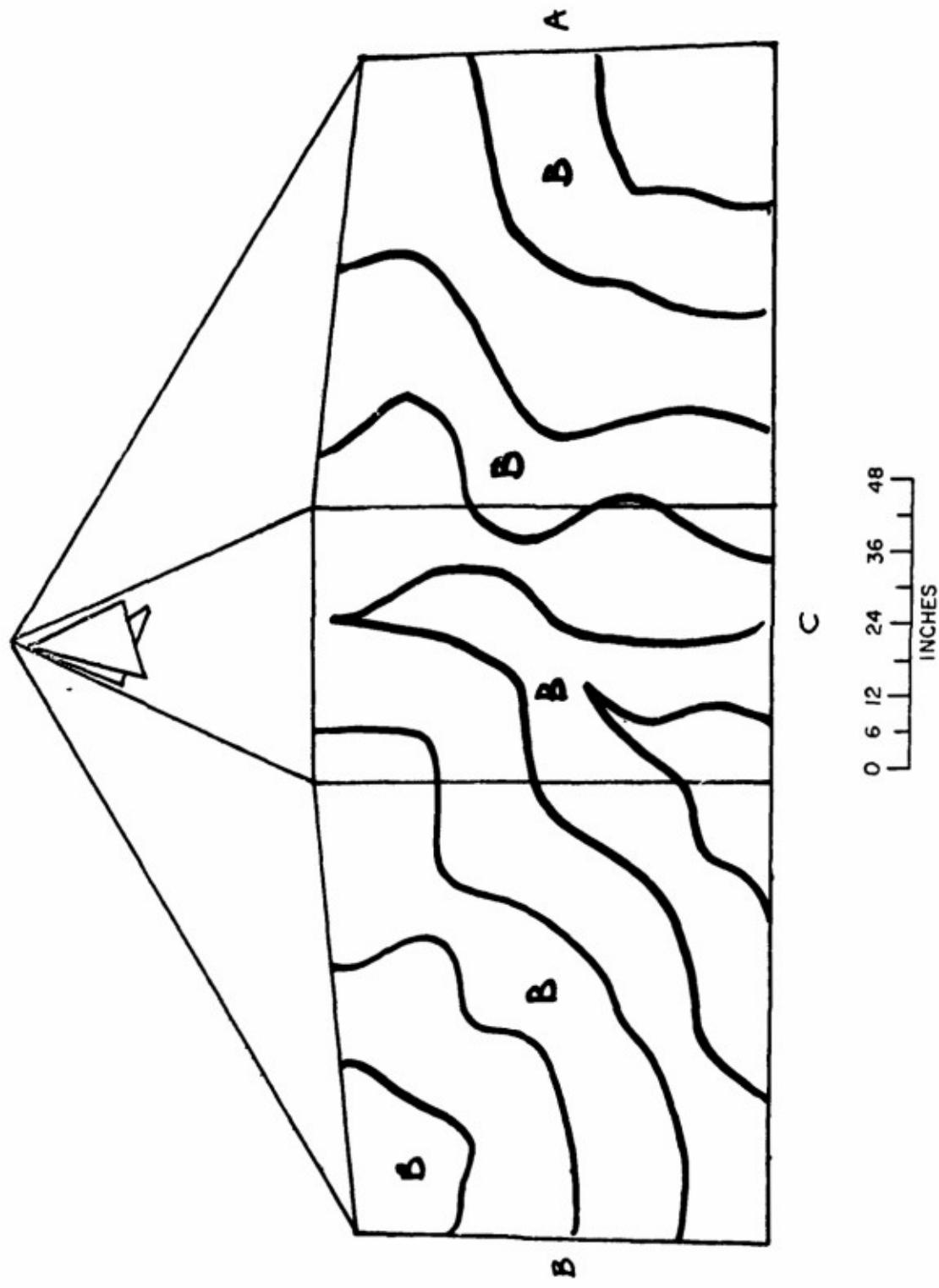


Figure B-1. Zebra Pattern - End C View - G.P. Medium

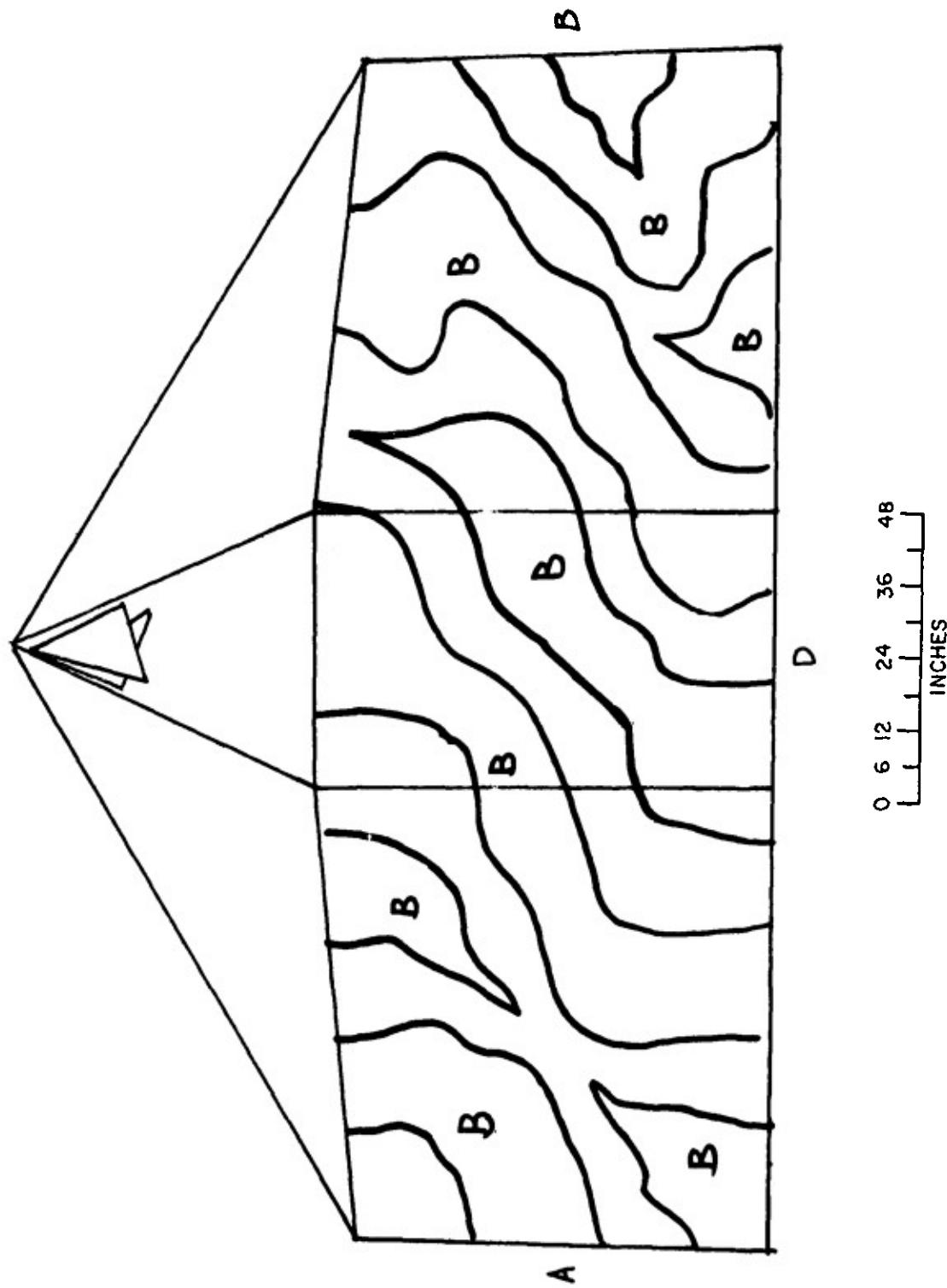


Figure B-11. Zebra Pattern - End D View - G.P. Medium

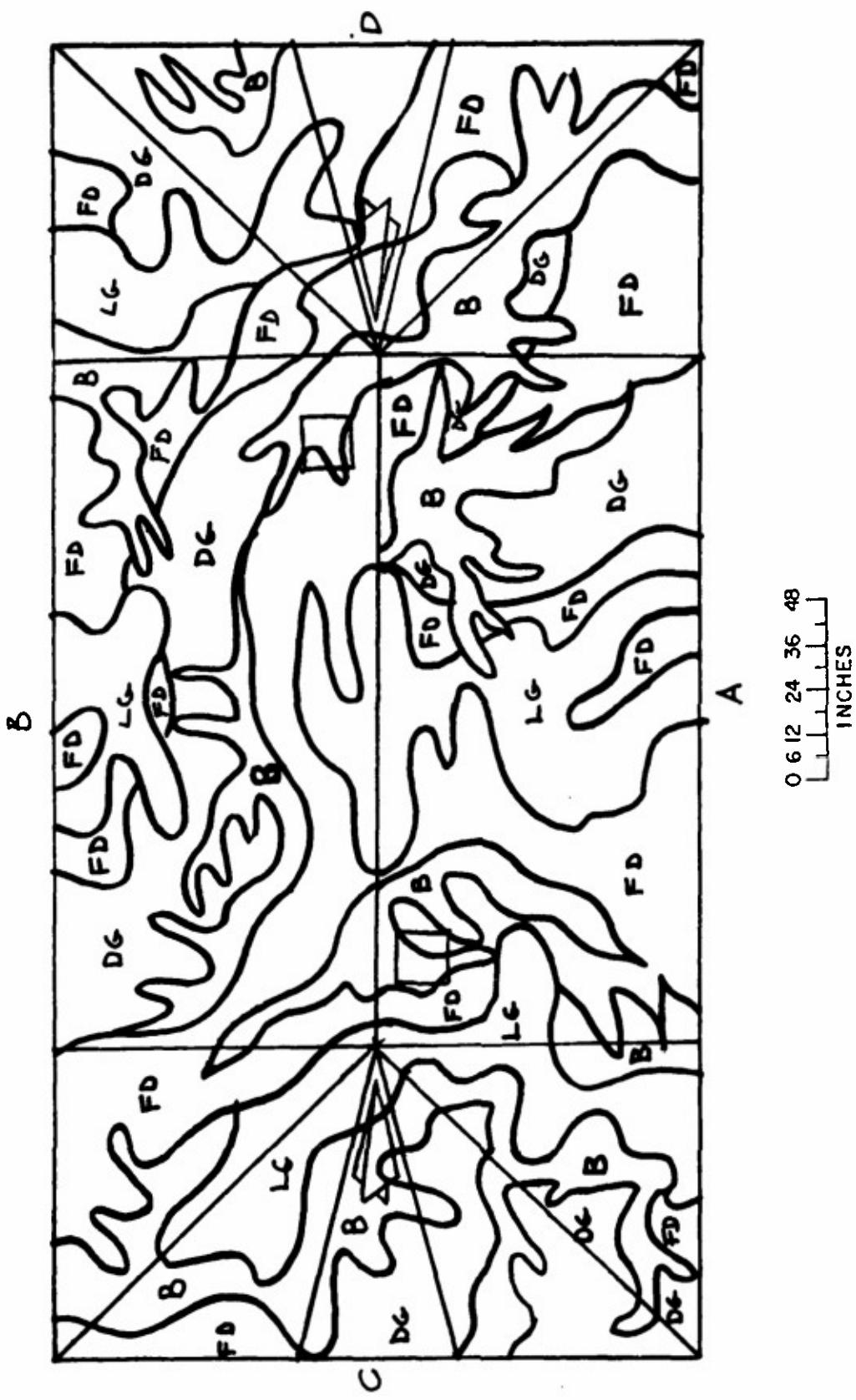


Figure B-15. Personnel Pattern (10X) Top View - G.P. Medium

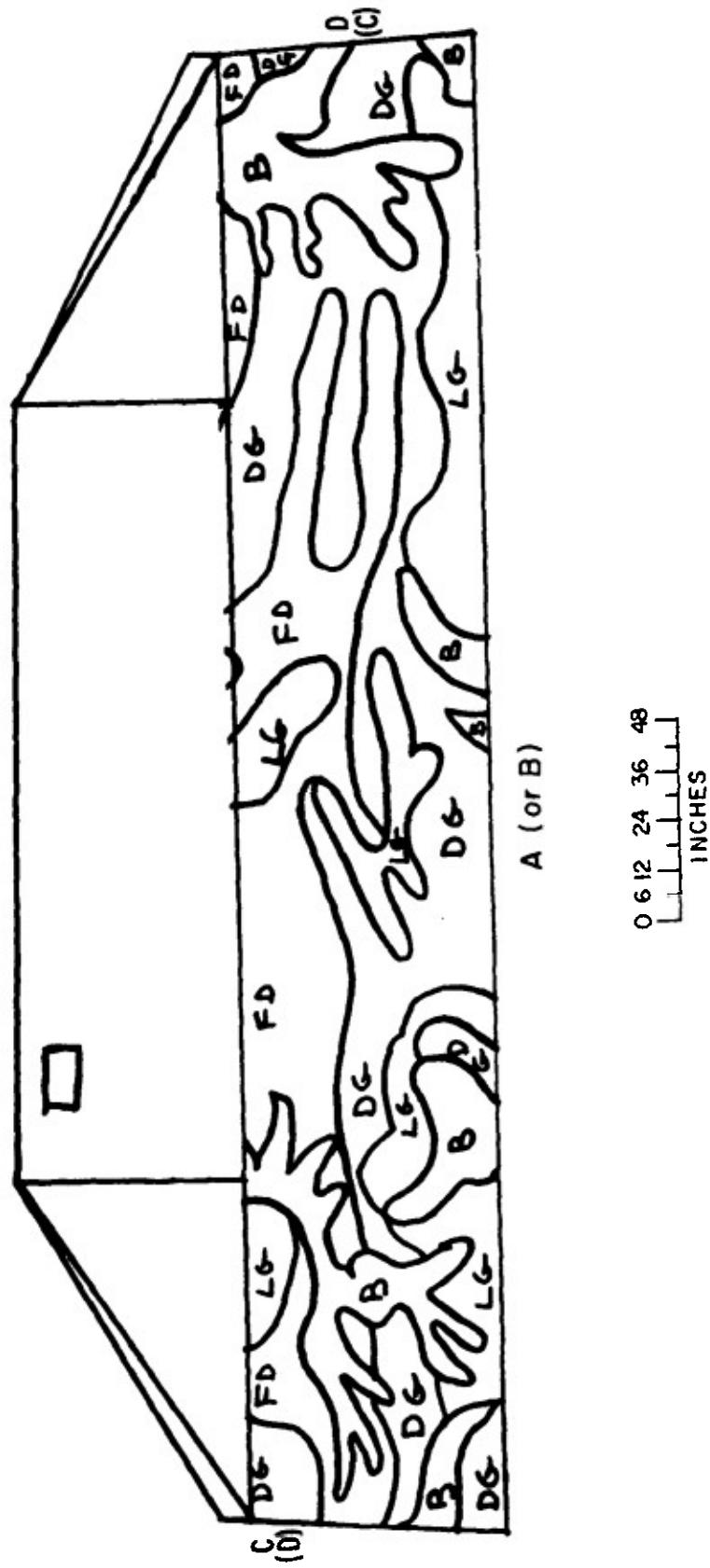


Figure B-1. Personnel Pattern (10X) Side View - G.P. Medium

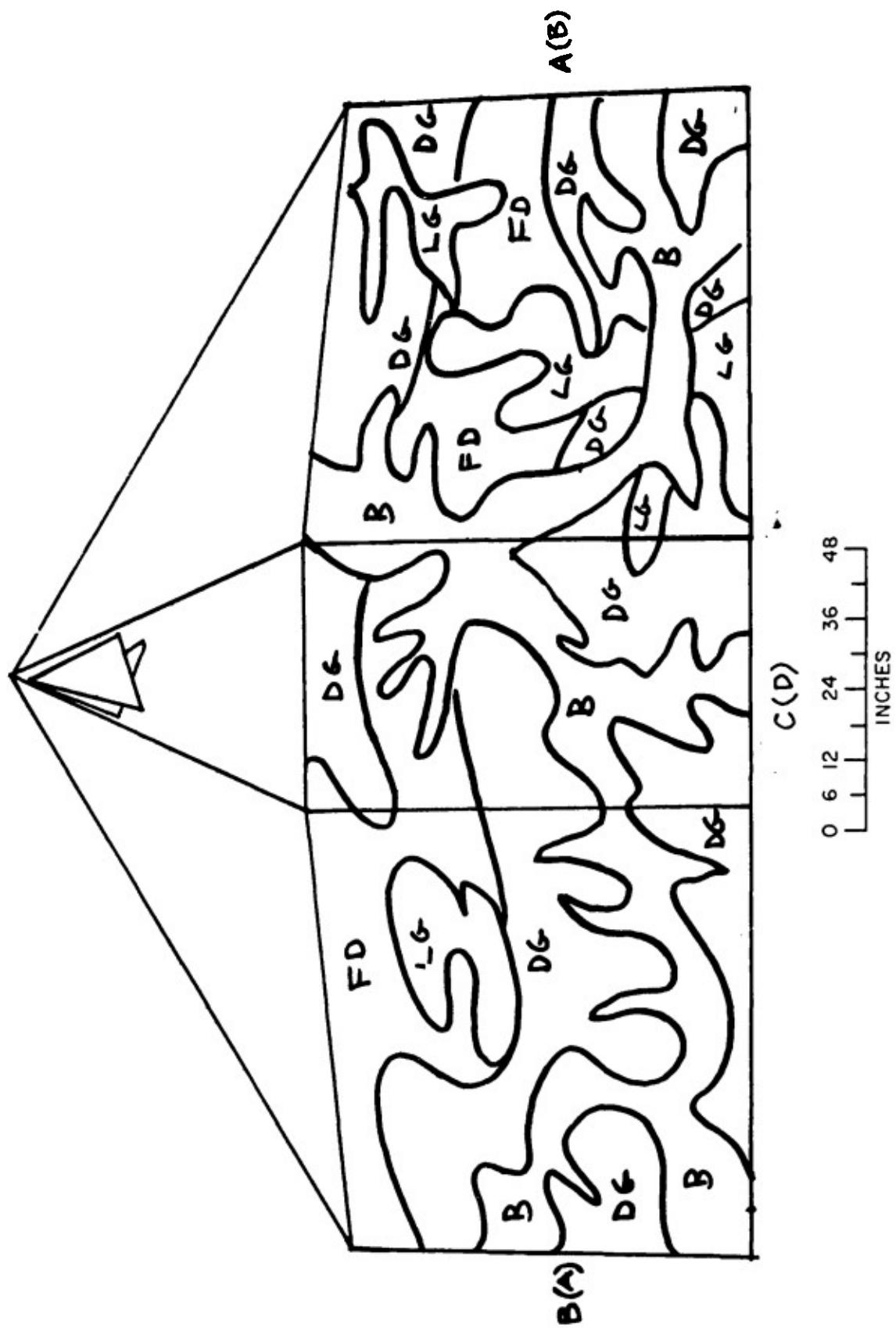
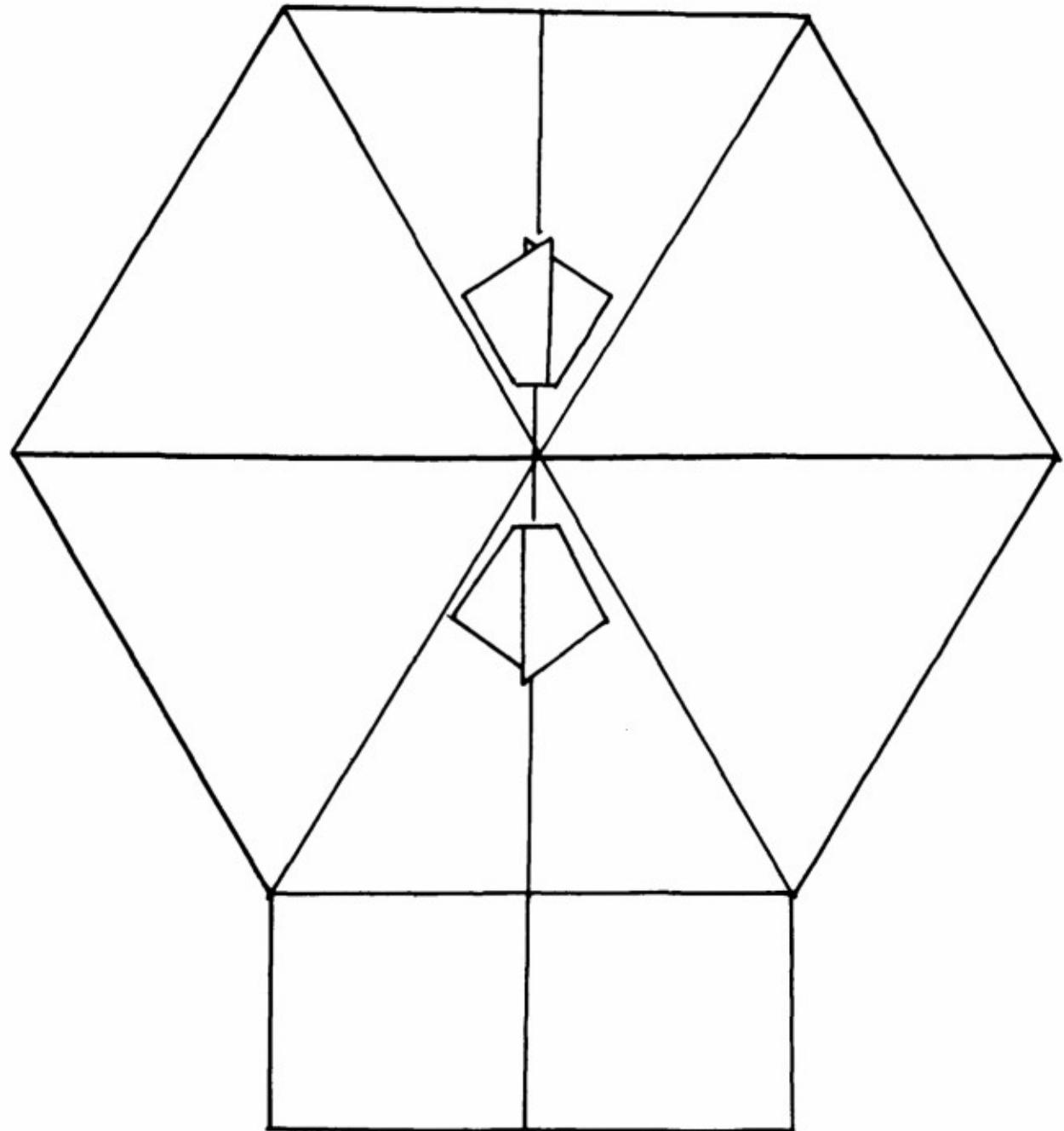


Figure B-1*i*. Personnel Pattern (10X) End View - G.P. Medium



0 6 12 24 36 48  
INCHES

Figure B-18. Top View - G.P. Small

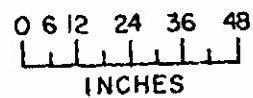
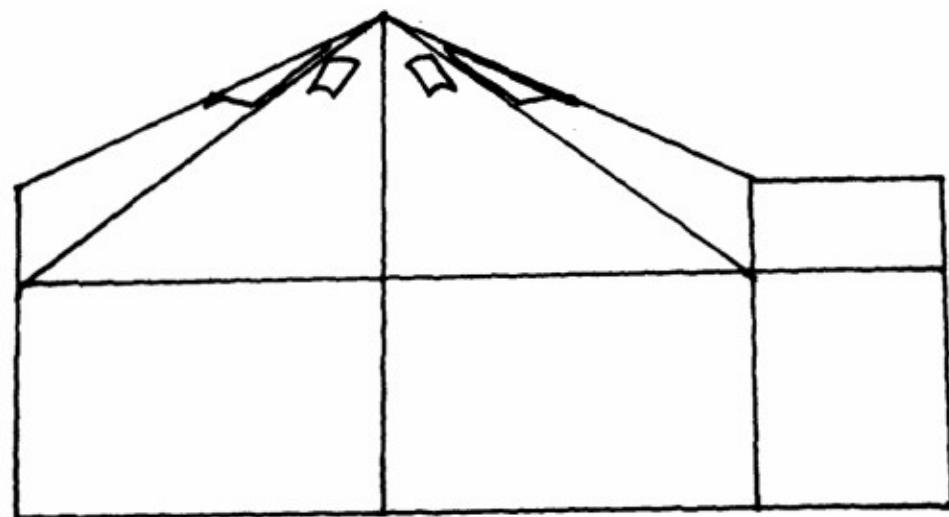
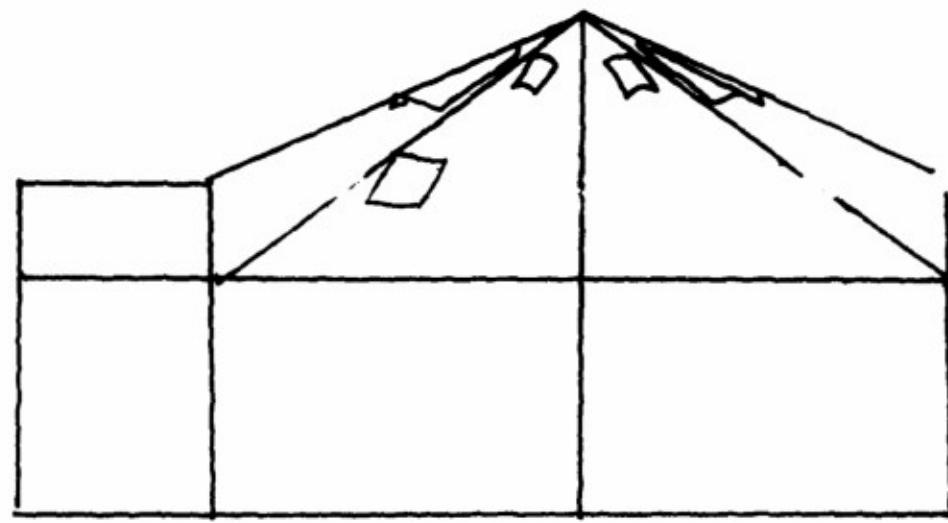


Figure B-19. Side Views - G.P. Small

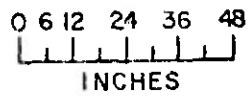
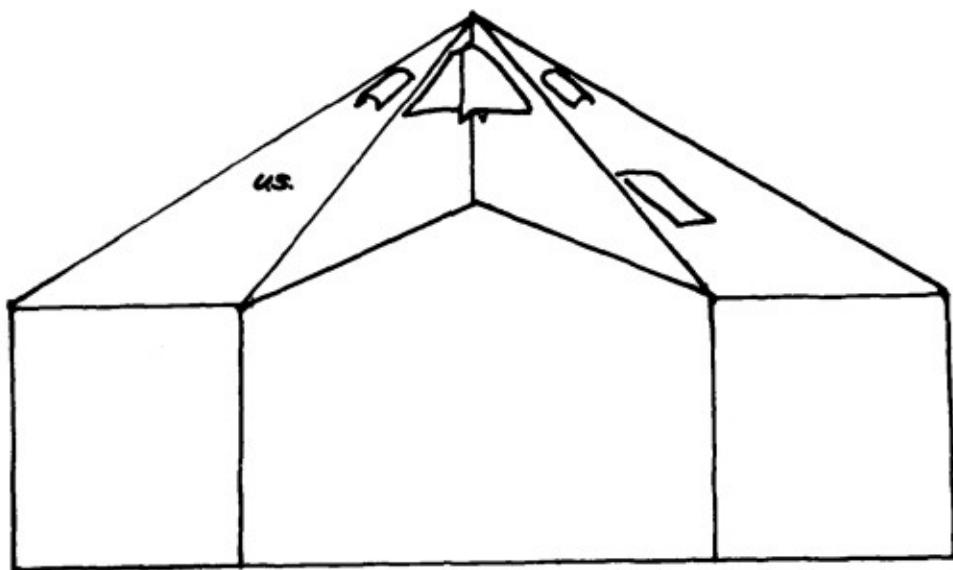
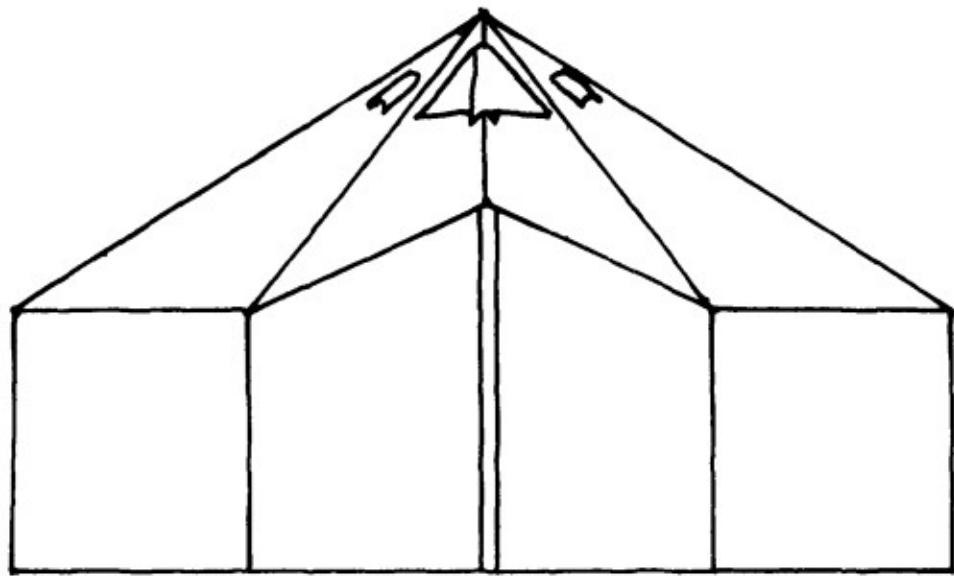


Figure B-20. End Views - G.P. Small

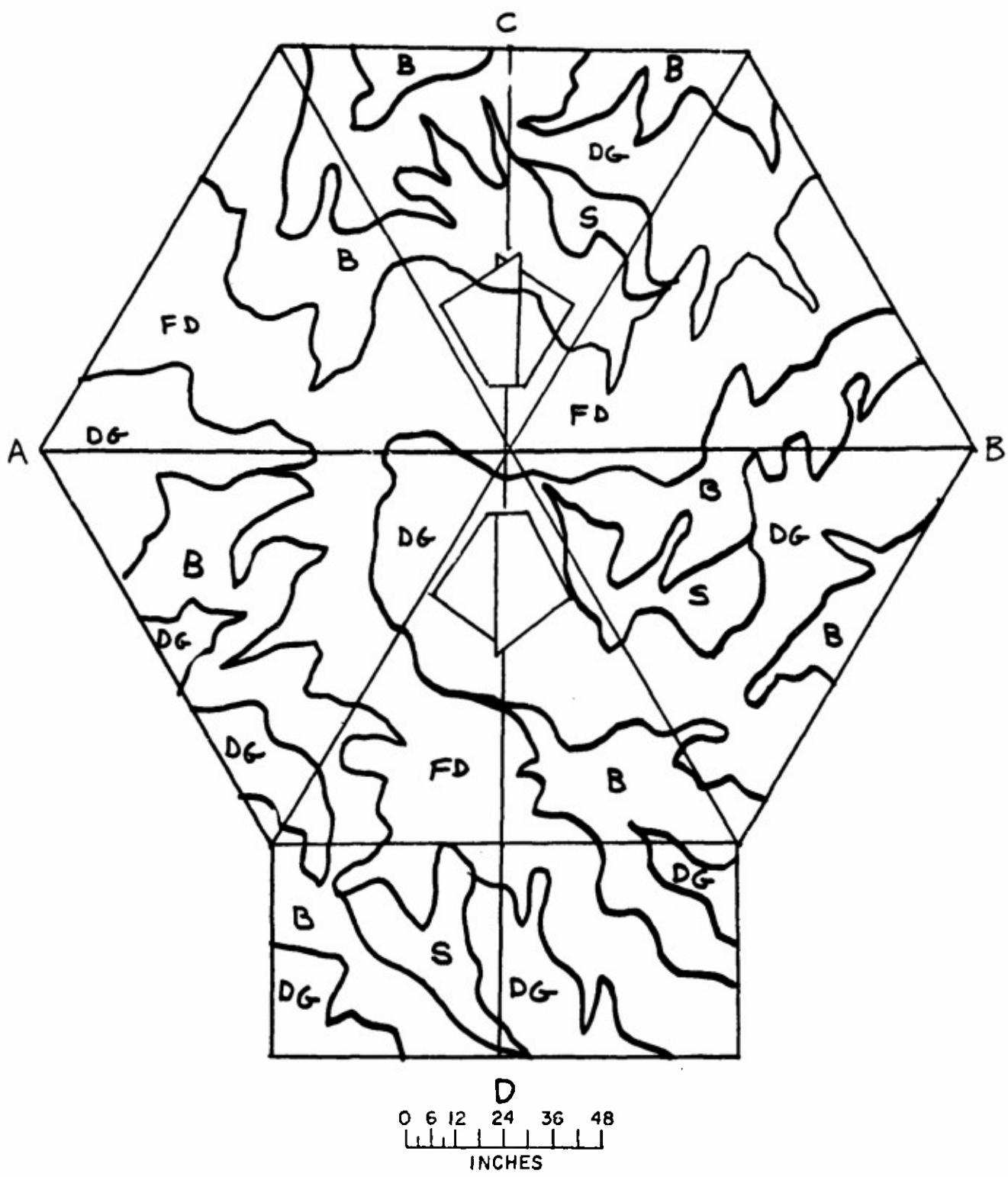
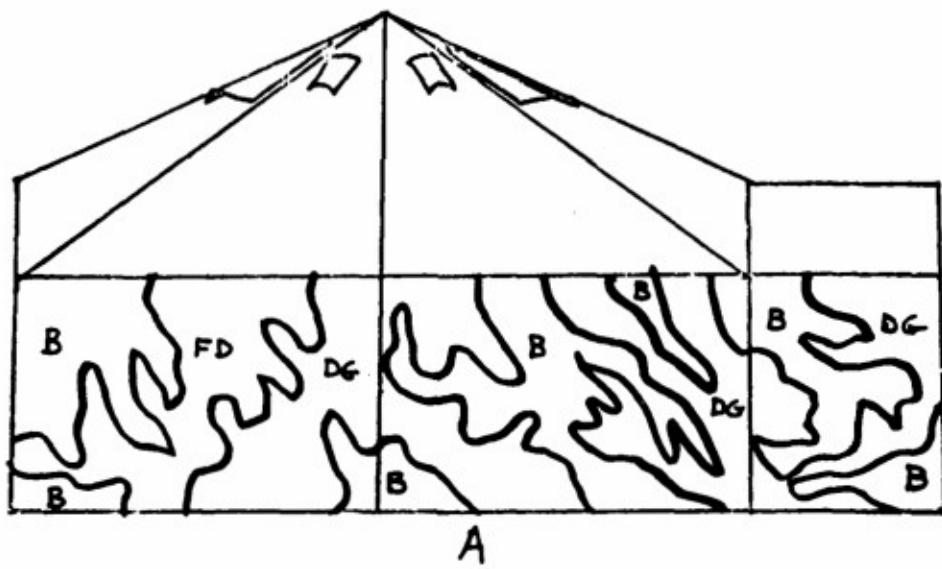
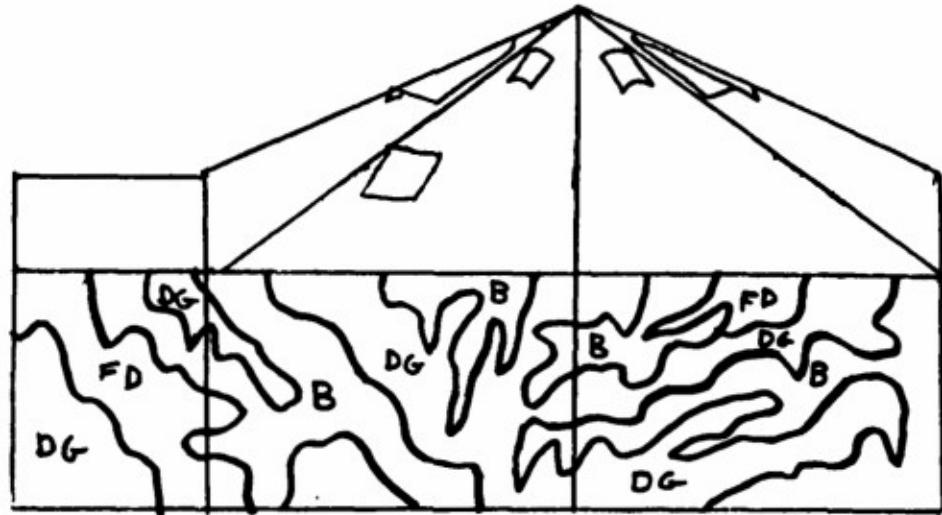
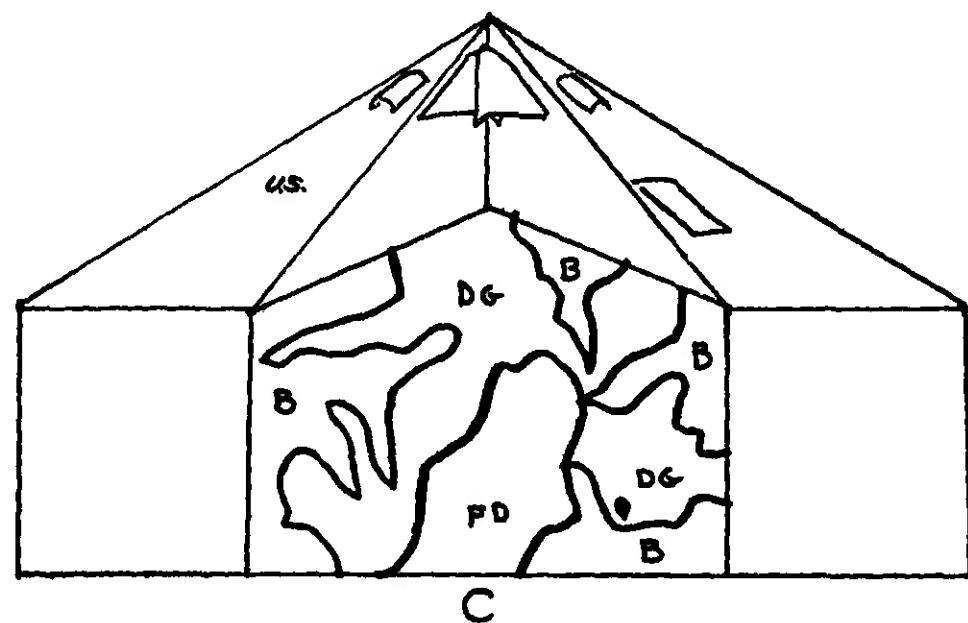
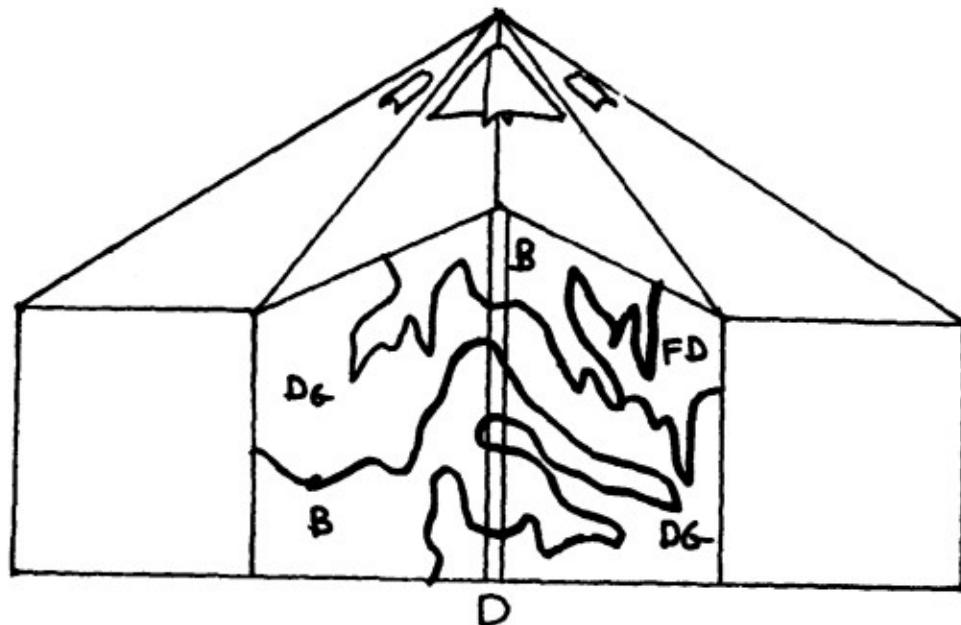


Figure B-21. Nature Pattern - Top View - G.P. Small



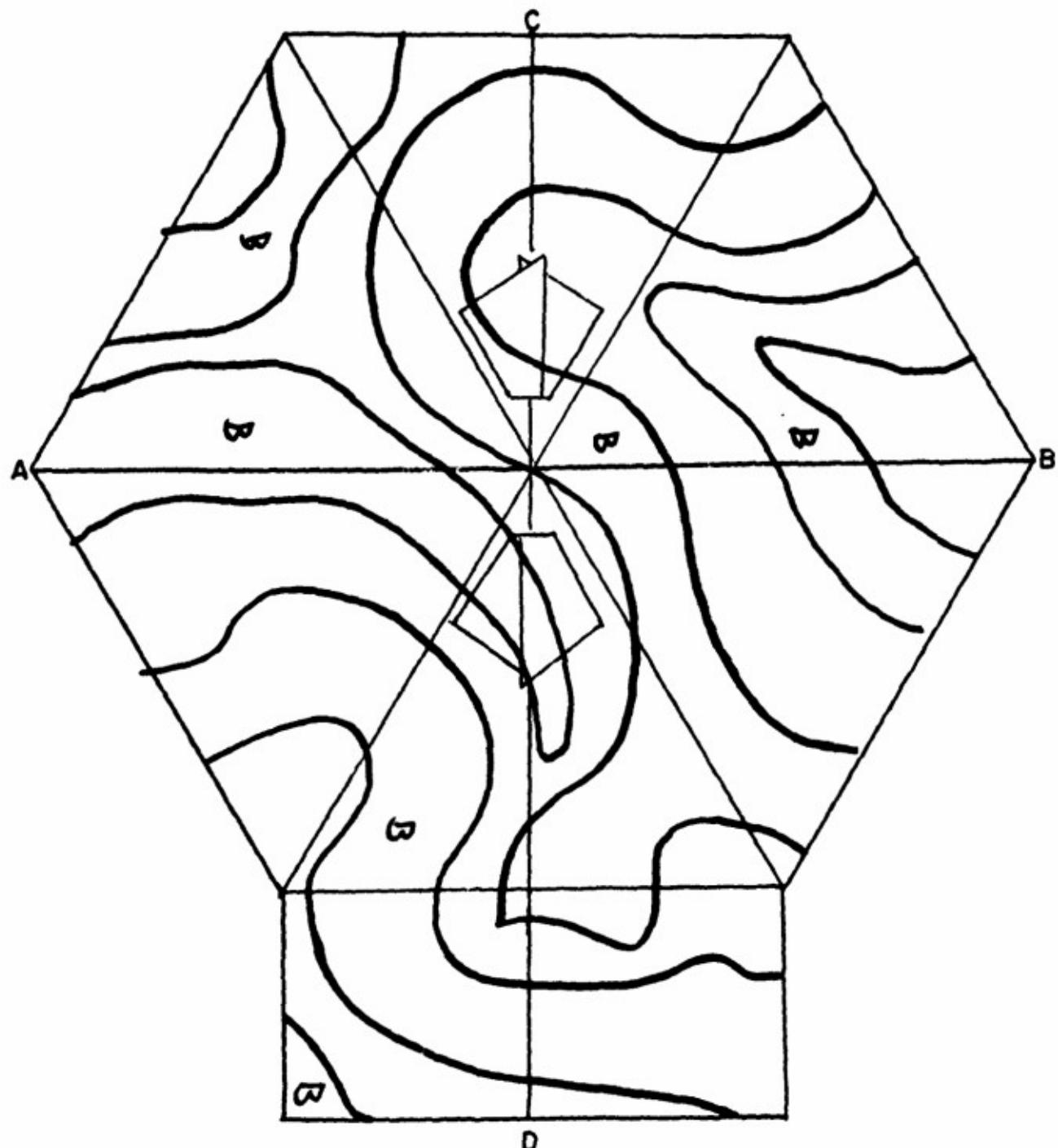
0 6 12 24 36 48  
INCHES

Figure B-22. Nature Pattern - Side Views - G.P. Small



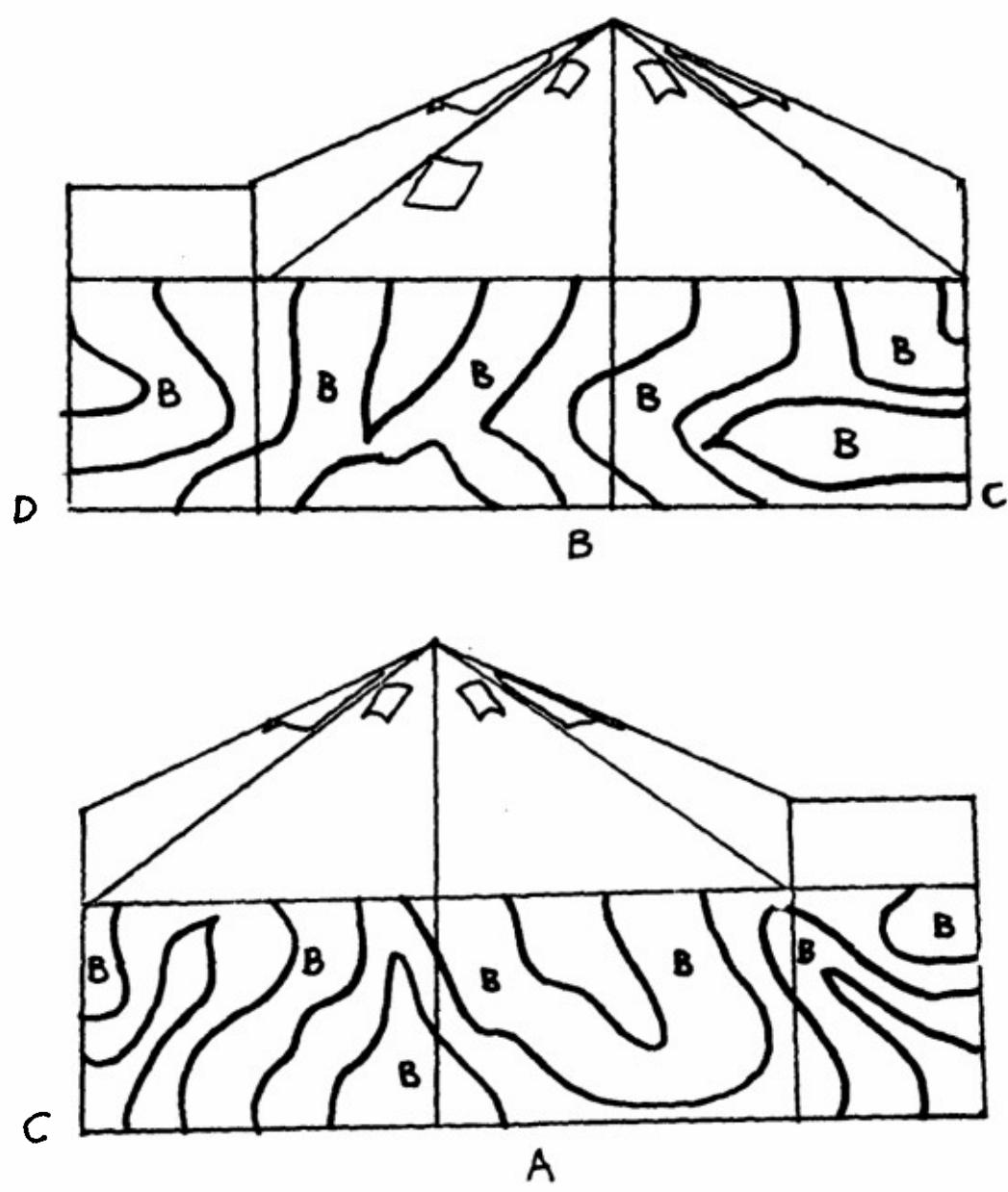
0 6 12 24 36 48  
INCHES

Figure B-23. Nature Pattern - End Views - G.P. Small



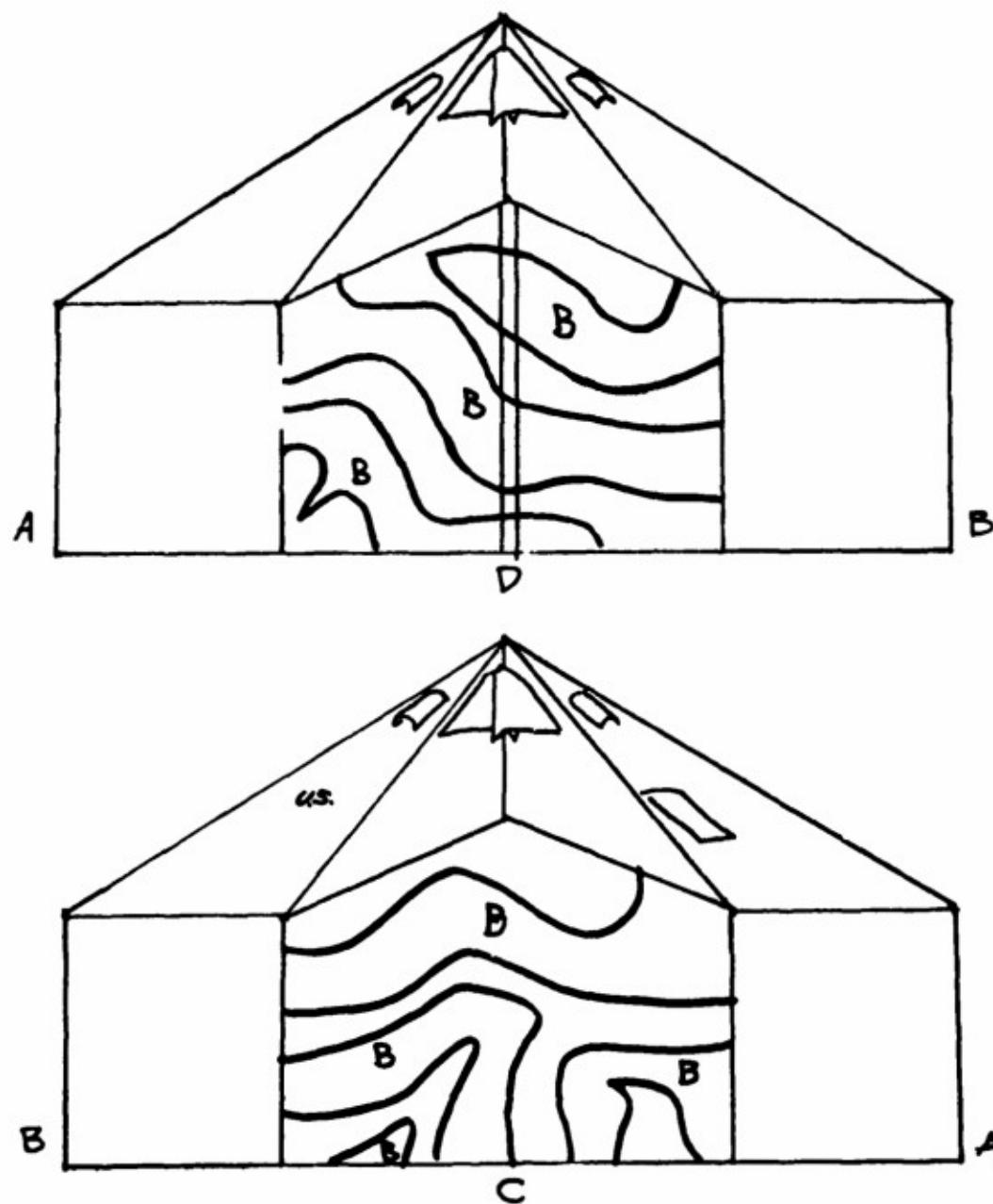
0 6 12 24 36 48  
INCHES

Figure B-21. Zebra Pattern - Top View - G.P. Small



0 6 12 24 36 48  
INCHES

Figure B-25. Zebra Pattern - Side Views - G.P. Small



0 6 12 24 36 48  
INCHES

Figure B-2. Zebra Pattern - End Views - G.P. Small

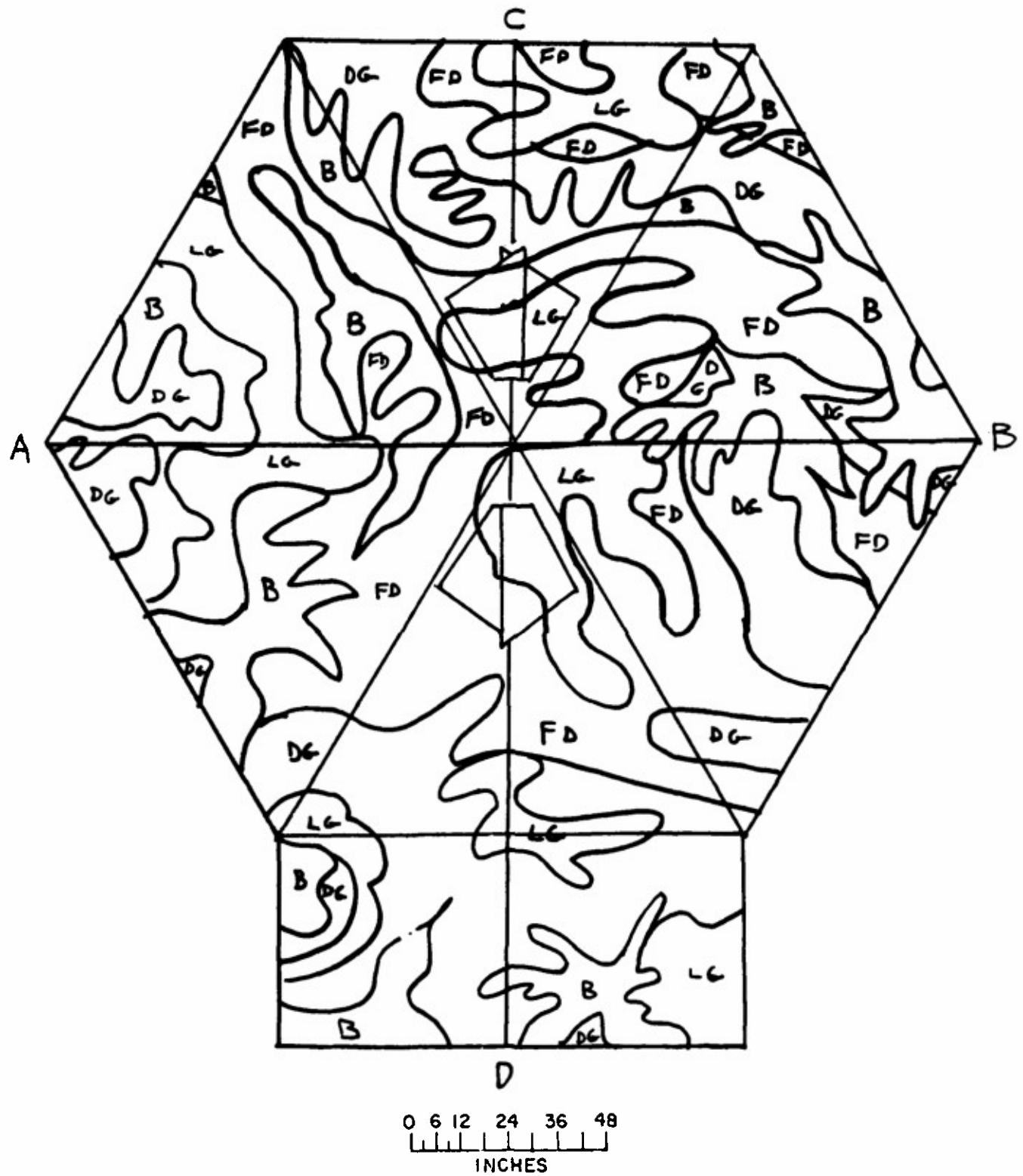
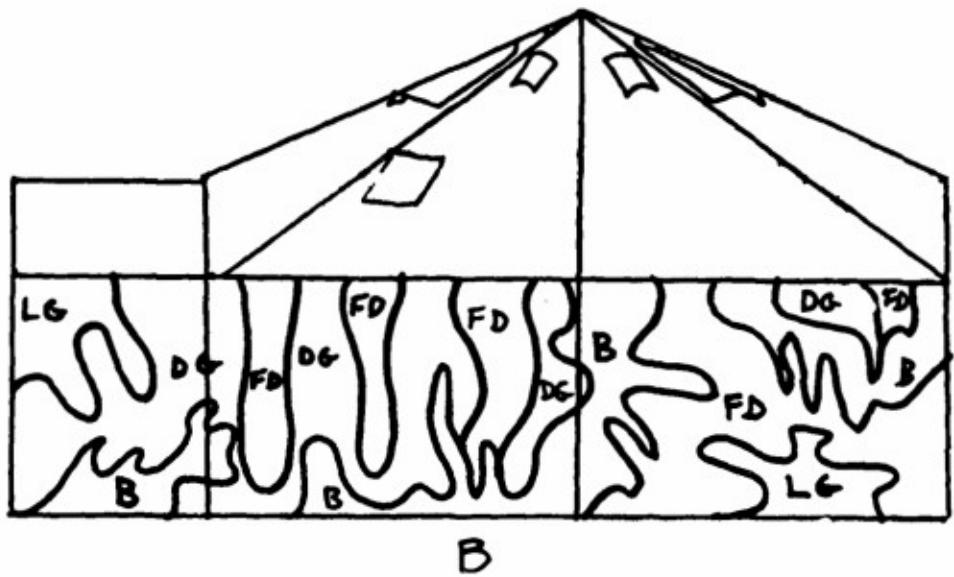
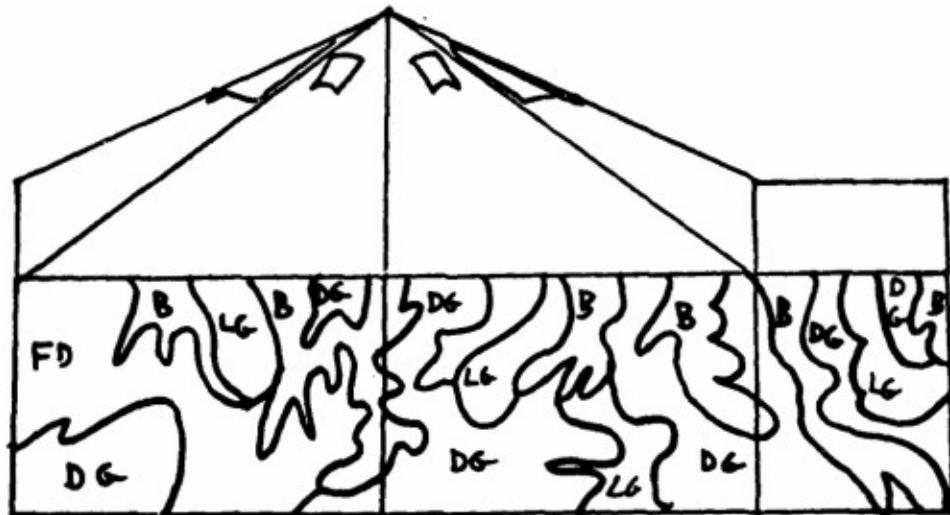


Figure 8-27. Personnel Pattern (10X) Top View - G.P. Small



B



A

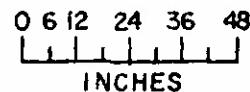
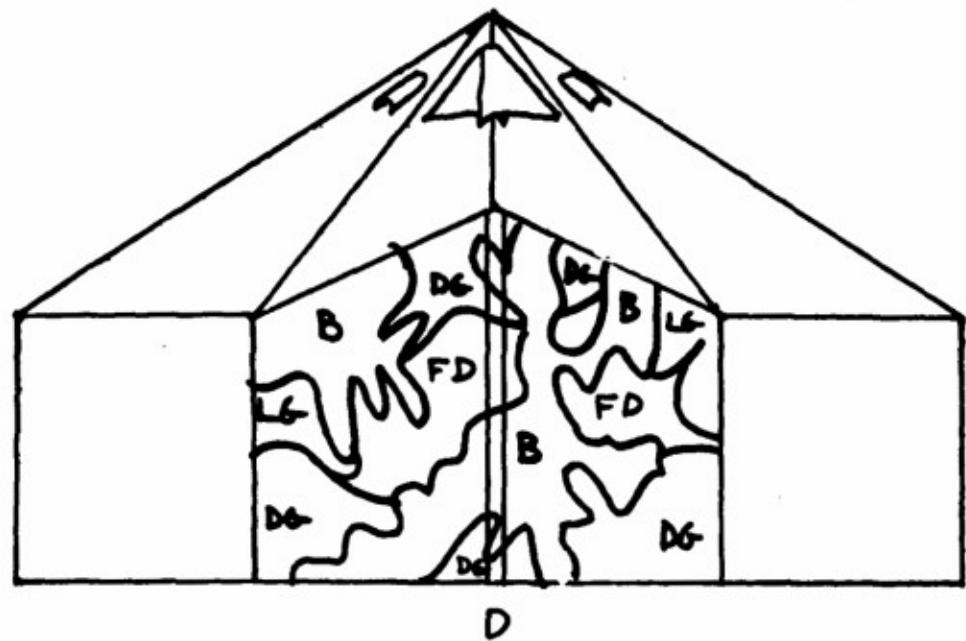
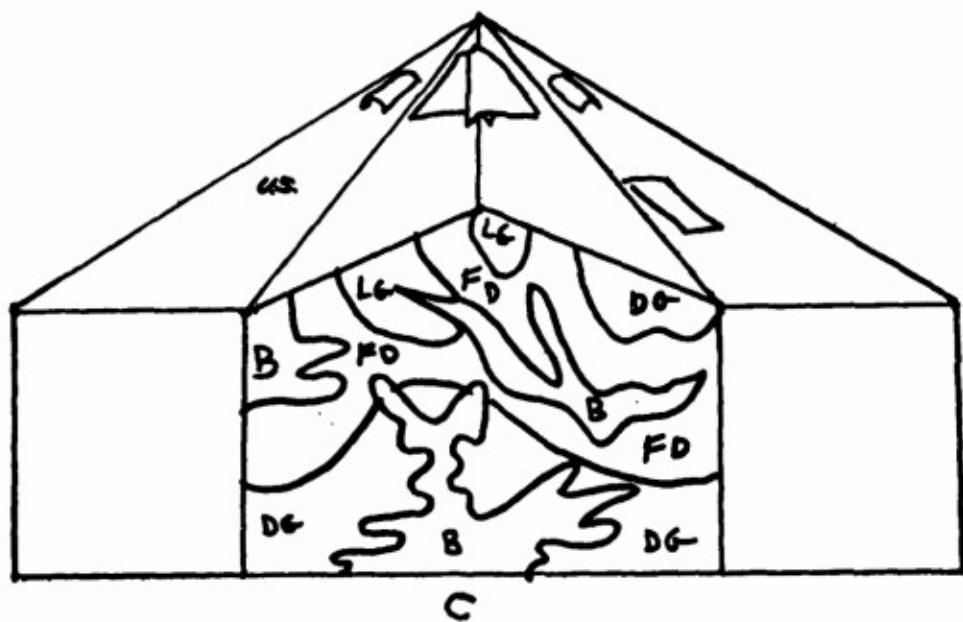


Figure B-28. Personnel Pattern (10x) Side Views - G.P. Small



D



C

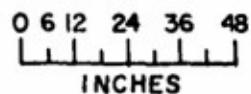


Figure B-29. Personnel Pattern (10X) End Views - G.P. Small

## **APPENDIX C**

### **REPORT ON GLOSS MEASUREMENTS**

**Genio Curves for Gloss Analysis of Overcoloring Compound**

**HUNTER ASSOCIATE LABORATORIES  
9529 LEE HIGHWAY  
FAIRFAX, VA 22030**

## APPENDIX C

### Gonio Curves for Gloss Analysis of Overcoloring Compound

#### ANALYSIS OF PRODUCT APPEARANCE

1. FOR: U.S. Army Natick Laboratories                    JOB NO.: 654  
ADDRESS: Natick, Mass. 01760                            DATE: 20 January 1975  
    HLAB REF: 4.7A

ATTENTION OF: Mr. Al Merola

REFERENCE: P.O. No. DAAK03-75-M-1198; 10/29/74, 12/30/74, 1/7/75

#### 2. SPECIMENS

PRODUCT: Low gloss coated fabric.

IDENTIFICATIONS: Identified by color and number of coats (1 or 2).

FORM: 5" x 8" swatches marked on back with color and number of coats. Ferro black, carbon black, dark green, field drab, each in 1 and 2 coats; sand in 2 coats only.

3. OBJECTIVES OF ANALYSIS: Provide gonio curves for specular reflectance  $i=V$ , and directional reflectance at  $i=15^\circ$  incidence.

#### 4. RESULTS AND CONCLUSIONS:

The goniophotometric curves are attached.

With illumination at  $45^\circ$ , reflection factors varied from a minimum of 2.6% for the two coat carbon black observed at  $30^\circ$  to a maximum of 60% for the same surface viewed at  $-85^\circ$ . The greatest change within any sample was this luminance range of 23 to 1; the least change was for the sand color, which varied only 3.3 to 1.

The specular angle variability extended from 100 to 1 up to 380 at 1 as angle was changed (cosine compensation on). Without cosine compensation, this variability ranged from 9.8 to 1 up to 35 to 1.

**Analysis of Product Appearance (cont'd)**

**INSTRUMENT USED:** Recording Goniophotometer      **SERIAL NO.:** 7  
**MODEL:** D10 - 5      **STD. NO.:** D10 - 130, 134  
**SCALES:**  $i=v$ , and reflectance at  $i=45^\circ$       **STD. VALUE:**  $Y = 90, 15$   
**SPECIAL MEASUREMENT CONDITIONS:** See experimental section - one additional page attached.  
**INSTRUMENT DATA (TABULATED RESULTS)**      **ADDITIONAL SHEETS ATTACHED**

**ANALYSIS OF DATA AND DISCUSSION**      No      **ADDITIONAL SHEETS ATTACHED**

The specular  $i=v$  curves were run both with and without cosine compensation. In previous work the cosine compensation was used to keep the  $i=v$  curve conditions as close to the  $i=45^\circ$  conditions as possible. Now we feel that  $i=v$  curves are better represented without cosine compensation, so both conditions are included for your reference and comparison.

**REFERENCES:**

HUNTER ASSOCIATES LABORATORY, INC.

BY:

HUNTERLAB APPLICATIONS LAB NO. 684 20 January 75

**5. EXPERIMENTAL**

**A. Goniophotometer Conditions**

**1. Reflectance Curves ( $i=45^\circ$ )**

The gonio conditions were set up to plot the gonio reflectance curves for the set of 9 samples on the same vertical or photometric scale. A white porcelain on steel standard with  $45^\circ/0^\circ$  reflectance of  $Y = 90$  was used for calibration, and the span was checked with a standard having  $Y = 15$ . The receptor slit was 13mm wide by 25mm high, at a distance of 285mm from the sample. The image of the source slit at the receptor window was 6mm wide by 13mm high. The spot size at the sample was 6mm wide by 14mm high. A Y filter plus a neutral density filter of 1.0 was placed in front of the photomultiplier tube (PMT). The lamp voltage was approximately 6.4 volts.

**2. Specular Curves ( $i=v$ )**

The  $i=v$  curves were run with the same geometry as the reflectance curves but with an additional 1.0 density neutral density filter in front of the PMT (2.0 N.D. total instead of 1.0). The lamp voltage was 5.6 volts. This permitted recording all the  $i=v$  curves on the same scale as in previous work.  $Y = 90 - Y = 15$  standards were read at  $45^\circ/0^\circ$ , and their scale reading were lower by a factor of 1.6 compared to the reflectance graphs.

**3. Curve Labelling**

The curves were coded for identification, and labelled clearly at each end. The curves were arranged in groups for easy comparison.

**B. Orientation of Samples**

The specimens were oriented with the 8 inch dimension in the plane of incidence, ie: the plane in which both the source and receptor lie.

DIO GONIOPHOTOMETER

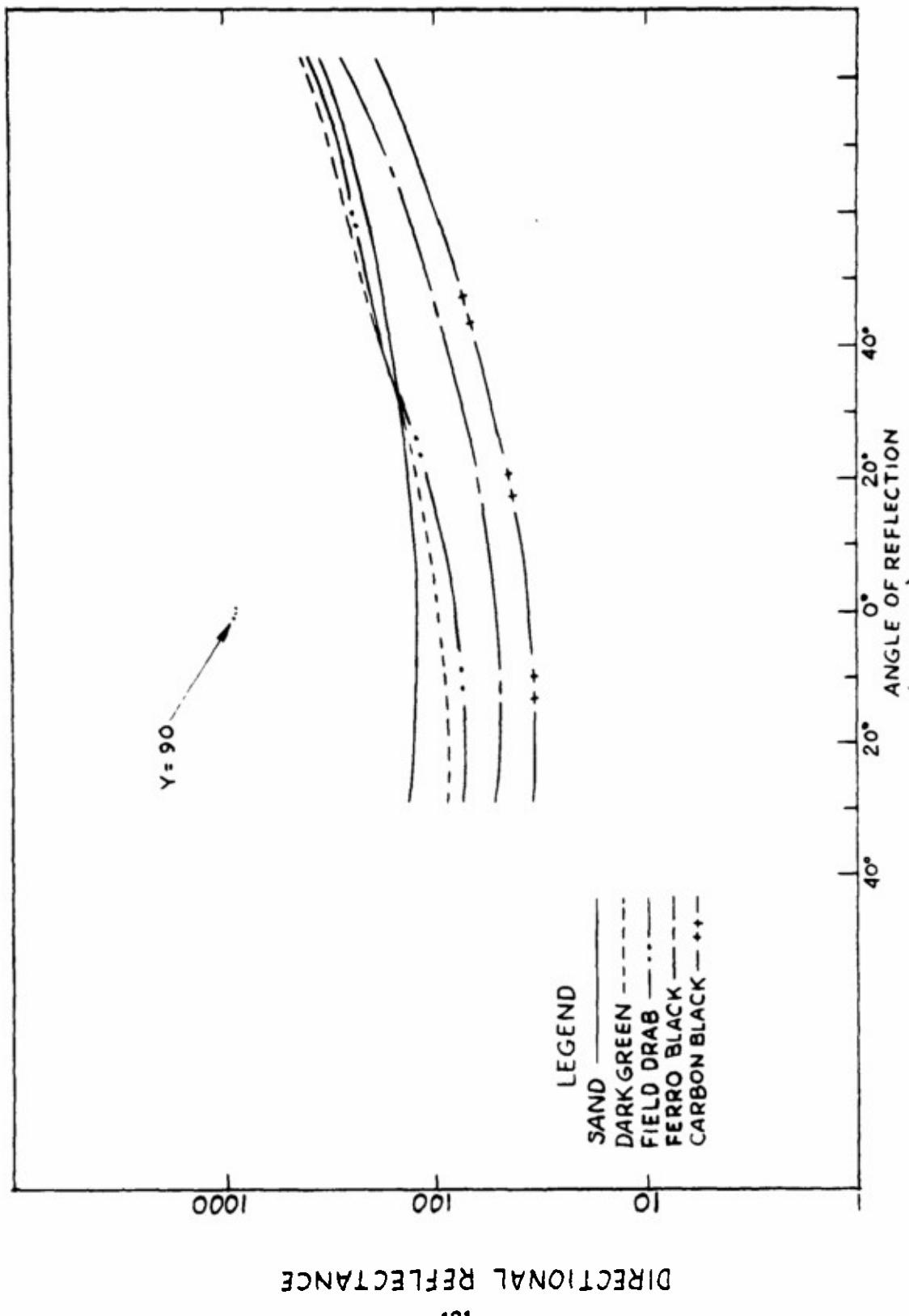


FIG. C1 LOW GLOSS FABRIC SWATCHES (1 COAT) ANGLE OF REFLECTANCE, FIXED DIRECTION OF INCIDENCE  $i = 15^\circ$ , COSINE COMPENSATION ON

DIO GONIOPHOTOMETER

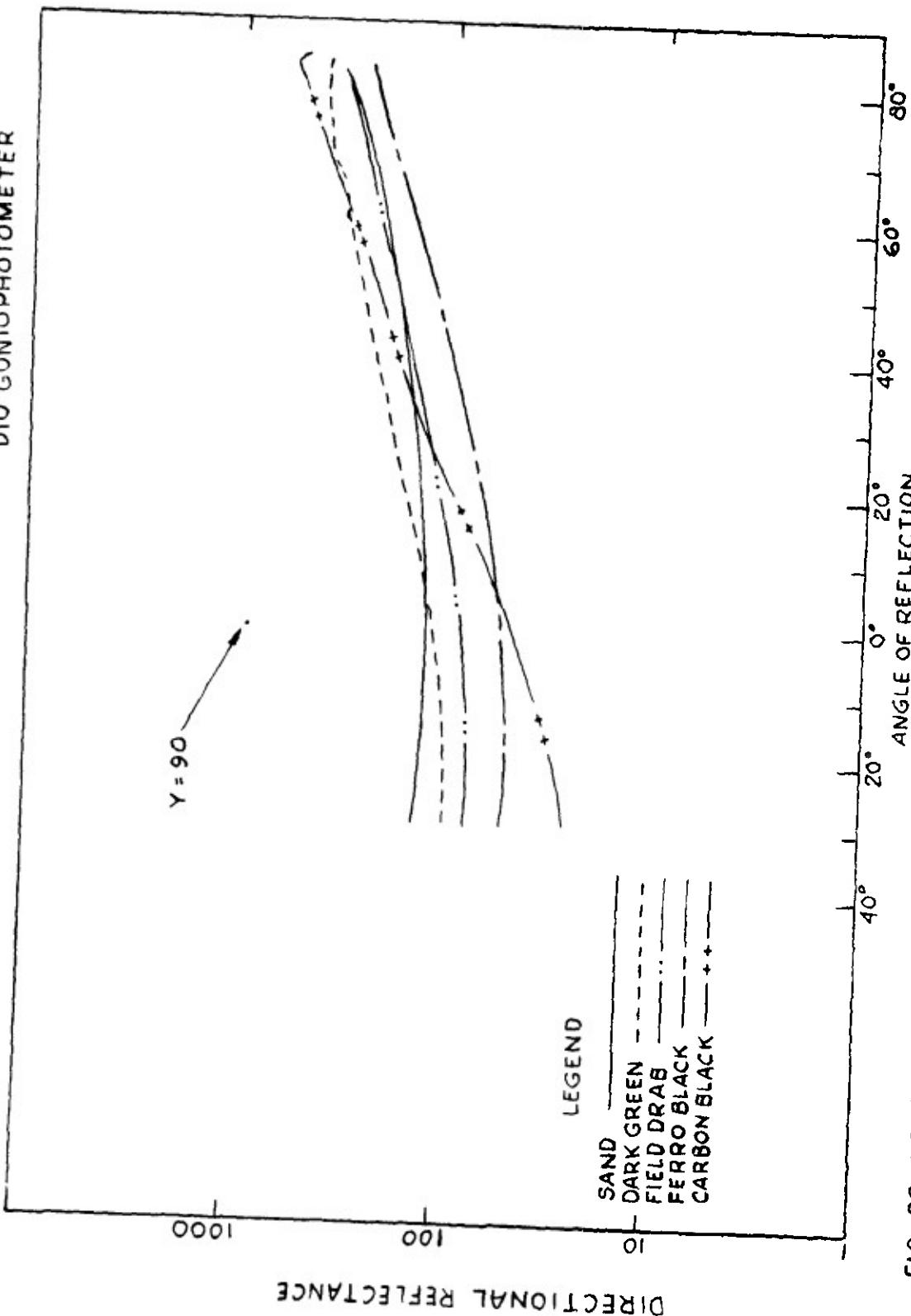
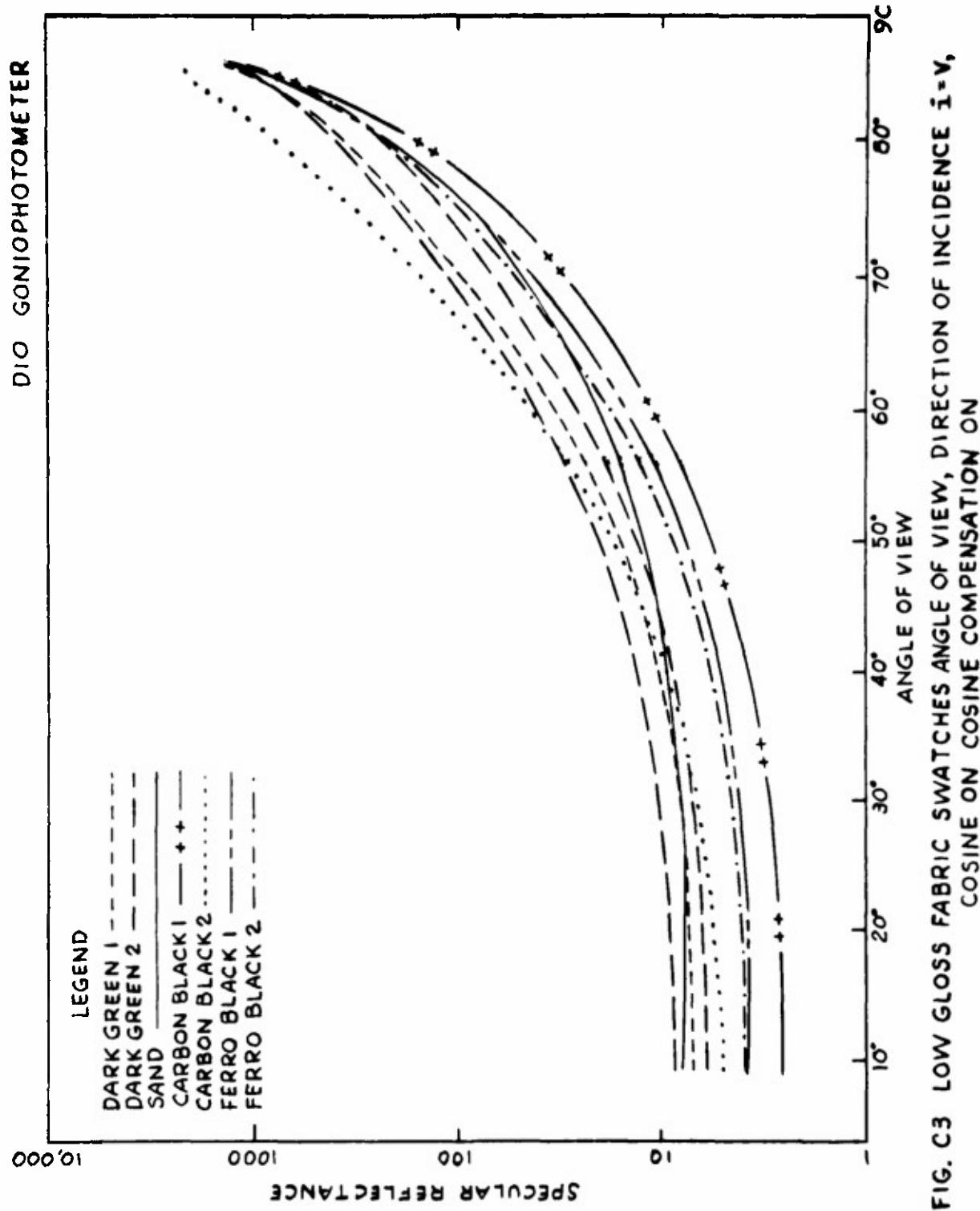


FIG. C2 LOW GLOSS FABRIC SWATCHES (2 COATS) ANGLE OF REFLECTANCE, FIXED DIRECTION  
OF INCIDENCE  $i = 45^\circ$ , COSINE COMPENSATION ON



**FIG. C3 LOW GLOSS FABRIC SWATCHES ANGLE OF VIEW, DIRECTION OF INCIDENCE  $\bar{i} = V$ , COSINE ON COSINE COMPENSATION ON**

DIO GONIOPHOTOMETER

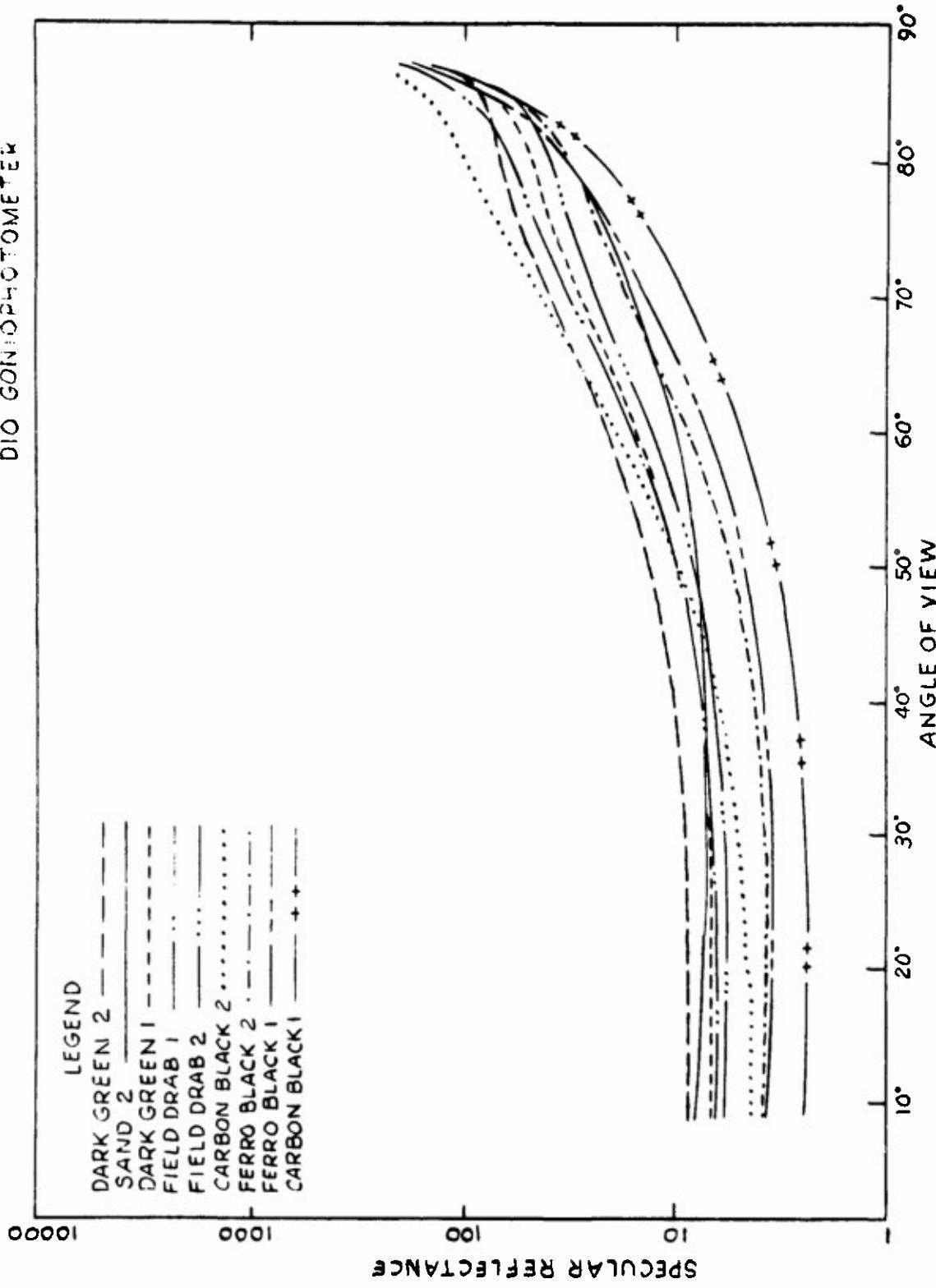


FIG. C4 LOW GLOSS FABRIC SWATCHES ANGLE OF VIEW, DIRECTION OF INCIDENCE i = V,  
COSINE OFF, COSINE COMPENSATION OFF

DIO GONIOPHOTOMETER

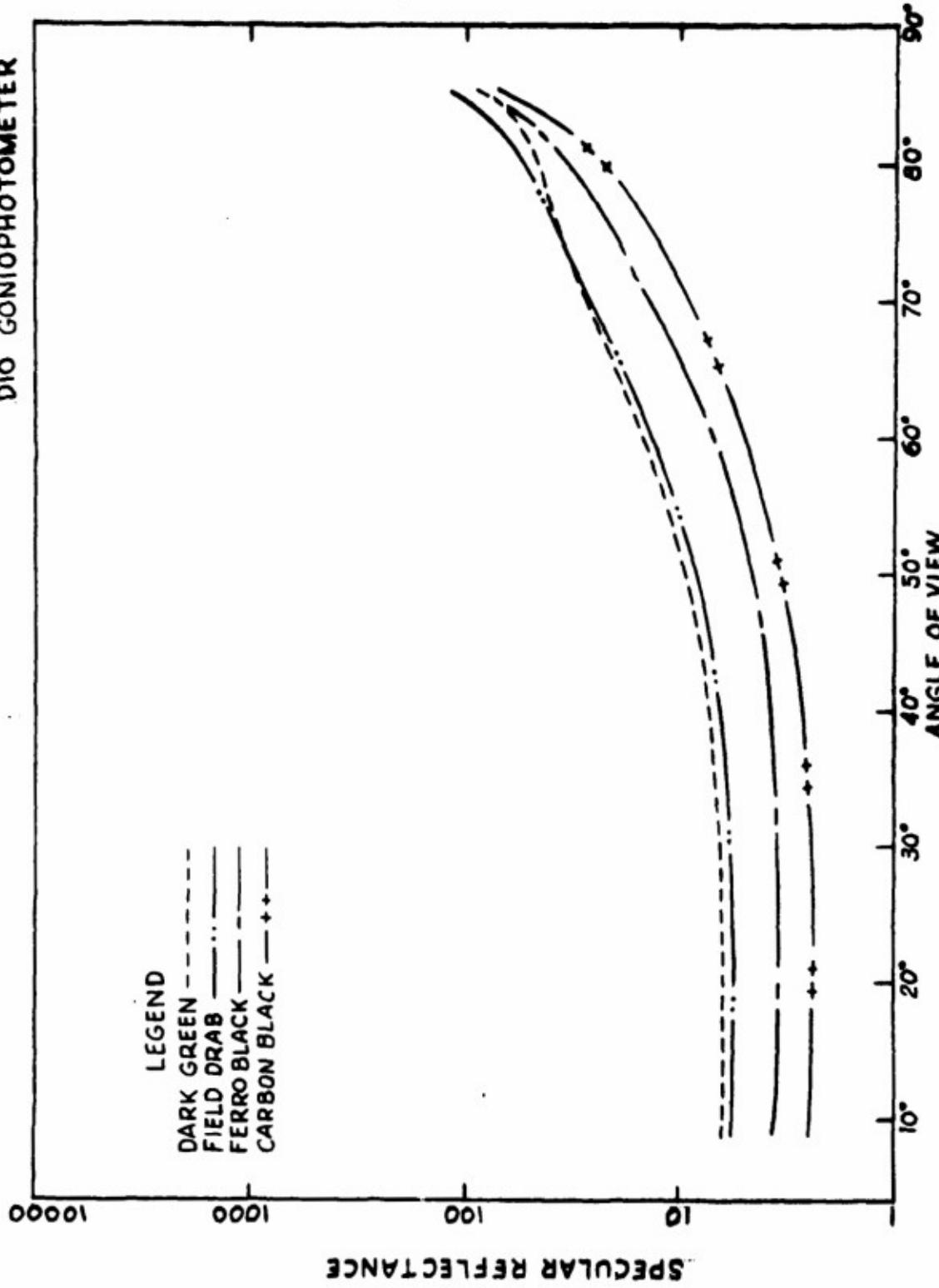


FIG. C5 LOW GLOSS FABRIC SWATCHES (1 COAT) ANGLE OF VIEW, DIRECTION OF INCIDENCE i.v., COSINE COMPENSATION OFF

DIO GONIOPHOTOMETER

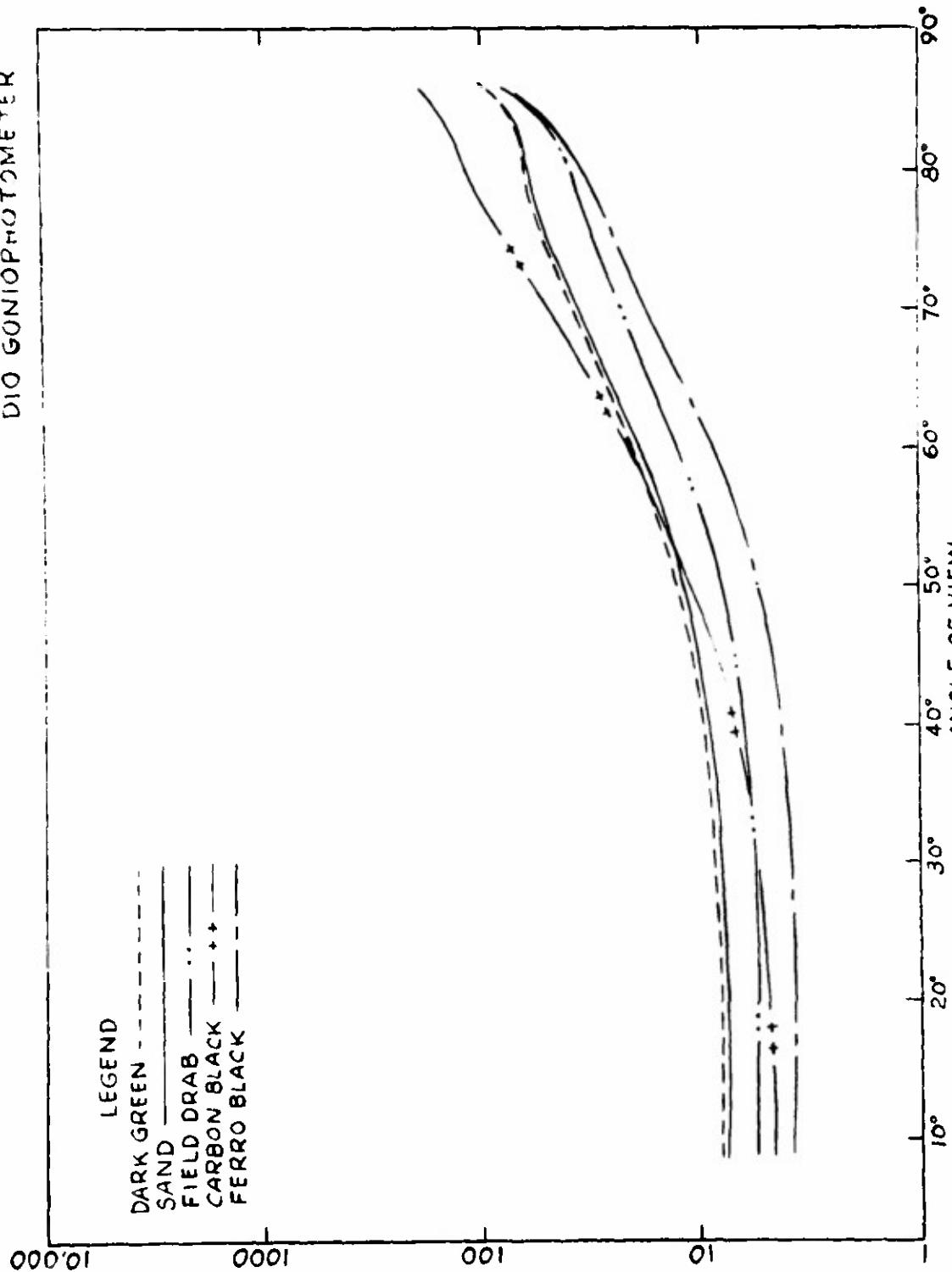


FIG. C6 LOW GLOSS FABRIC SWATCHES (2 COATS) ANGLE OF VIEW DIRECTION OF INCIDENCE  $i = V$ , COSINE COMPENSATION OFF